



Water Quality Monitoring of Wadeable Streams in the North Coast and Cascades Network

*2012-2015 results from Ebey's Landing National Historical
Reserve and Lewis and Clark National Historical Park*

Natural Resource Data Series NPS/NCCN/NRDS—2018/1182



ON THE COVER

Looking upstream in the Skipanon River sample reach, in Lewis and Clark National Historical Park.
NPS Photo.

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Summary and Key Findings

The North Coast and Cascades Network Water Quality Monitoring Program and protocol focuses on monitoring wadeable streams in the North Coast and Cascades Network most at risk of water quality impairment. This report summarizes the monitoring results from 2012 to 2015 for four streams located in Ebey's Landing National Historic Reserve and the Lewis and Clark National Historic Park located in Washington and Oregon States. In 2012, the North Coast and Cascades Network established a referenced sample reach and permanent continuous water temperature monitoring station within each of these streams and conducts a single annual survey to download water temperature data; measure dissolved oxygen, pH, specific conductance, and turbidity; measure stream and riparian habitat conditions; collect benthic invertebrate samples; and survey for invasive plant and animal species. Results from these monitoring activities have found that:

- Ebey's Watercourse; Ebey's Landing National Historic Reserve
 - Is dewatered for up to 26% of the year and exceeded Clean Water Act standards for temperature in 2015;
 - Meets Clean Water Act standards for pH and dissolved oxygen when flow is present;
 - Has been colonized by four species of invasive plants, although in 2015 surveys found these plants were all dead;
 - Supports a depauperate benthic macroinvertebrate assemblage consisting of non-insects and midge taxa;
 - Contained the non-native fathead minnow (*Pimephales promelas*).
- The Skipanon River; Lewis and Clark National Historic Park
 - Exceeded Clean Water Act standards for water temperature and has not met the minimum threshold for dissolved oxygen concentration since monitoring was initiated in 2012;
 - Has been colonized by five species of invasive plants;
 - Has been colonized by the invasive New Zealand mud snail (*Potamopyrgus antipodarum*);
 - Supports a depauperate benthic macroinvertebrate assemblage consisting primarily of mollusks and amphipods.
- Colewort Creek; Lewis and Clark National Historic Park
 - Has met all established Clean Water Act standards since monitoring was initiated;
 - Had a three day exceedance in water temperatures that might influence salmon and trout spawning and incubation;
 - Contained small patches of two invasive plant species in 2015;
 - Has not shown evidence of invasive New Zealand mud snail colonization;

- o Supported a moderately diverse array of benthic macroinvertebrates typically dominated by non-insect, midge, and stonefly taxa.
- Megler Creek; Lewis and Clark National Historic Park
 - o Has met all Clean Water Act standards since monitoring was initiated;
 - o Contained one invasive plant species in 2015;
 - o Has not shown evidence of colonization by the invasive New Zealand mud snail, however one individual was collected in 2013 and none have been documented since;
 - o Supports a diverse array of benthic macroinvertebrates dominated by mayflies, stoneflies, and dipteran taxa.

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Glossary

List of terms

Term	Definition
303(d)	Section of the Clean Water Act mandating that states submit a list of water bodies not meeting or not expected to meet water quality standards.
7-day Average of the Maximum Daily Temperature (A7DMT)	The moving 7-day average of the daily maximum temperature.
Accuracy	The overall measure of agreement of a measurement to a known value.
Bankfull Width	Perpendicular measurements of the channel that contains bankfull (or every other year flooding) discharge.
Bias	A distortion in measurements that causes errors in one direction.
Children Taxa	A taxon that occurs immediately below another taxon in a taxonomic hierarchy.
Clean Water Act	1972 statute that established structure for regulating pollutant discharges into and quality standards for surface waters of the U.S.
Ecological condition	Defined by the Environmental Protection Agency as “the state of physical, chemical and biological characteristics of the environment, and the processes and interactions that connect them.”
Ecoregion	Ecological regions having similar climate, vegetation, soil type, and geology. Ecoregions as defined by the EPA are areas within which ecosystems (and the type, quality, and quantity of environmental resources) are generally similar.
Index period	The index period is the period of time that water quality samples should be collected to minimize seasonal and diel variation.
Intermittent waters	Streams that flow only during part of the year, such as in the spring and early summer after snowmelt, or ponds and wetlands that seasonally dry out.
O/E (Observed/Expected)	A ratio of the number of taxa expected (E) to exist at a site to the number that are actually observed (O). The taxa expected at individual sites are based on models developed from data collected at reference sites.
Parent Taxa	A taxon that occurs immediately above another taxon in a taxonomic hierarchy.
Perennial stream	A stream that flows continuously throughout the year.
Precision	Agreement among repeated measurements of the same property under identical or substantially similar conditions.
Reference condition	Represents the least human disturbed condition available in the NCCN for a given habitat. Reference condition waters are only found in watersheds free of the impacts resulting from lasting ground disturbance or land clearing, including maintained trails, and are used as benchmarks to compare the condition of other waters in the NCCN.
RIVPACS	An aquatic biomonitoring system for freshwater rivers and streams using the macroinvertebrate communities found at the study site during sampling.
Sample Reach	A discrete segment of stream delineated as 40 times the mean wetted width; determined during reach delineation in the first year of survey and remains consistent from year to year.
Sensitivity	The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest.

List of terms (continued)

Term	Definition
Species of concern	A term used to describe a species about which the park is concerned because the species is vulnerable to population or habitat loss within the park but does not appear on federal or state ESA listings.
Status	Some statistic of a parameter over all monitoring sites within a single or well-bounded window of time.
Taxon	A general term that refers to a taxonomic group rank, such as a species, family or class.
Thalweg Depth	The line of lowest elevation within a watercourse.
Trend	A non-cyclic, directional change in a response measurement that can be with or without pattern.
Wadeable stream	A stream that is small and shallow enough to adequately sample by wading, without a boat.
Wetted Width	Perpendicular measurements of the stream channel covered in water.

Acronyms and Abbreviations

Acronym or Abbreviation	Definition
m	meter
°C	Degrees Celsius
μS/cm	microsiemens per centimeter
mg/L	milligrams per liter
AMS	Alternate measure sensitivity
CWA	Clean Water Act
DEQ	Oregon Department of Environmental Quality
DO	Dissolved oxygen
EBLA	Ebey's Landing National Historical Reserve
EPA	Environmental Protection Agency
LEWI	Lewis and Clark National Historical Park
MQO	Measurement Quality Objective
NCCN	North Coast and Cascades Network
NPS	National Park Service
NTU	Nephelometric turbidity unit
OE	Observed to expected ratio
PD	Percent Difference
RIVPACS	River Invertebrate Prediction and Classification System
RPD	Relative Percent Difference
SOP	Standard operating procedure
USGS	United States Geological Survey

Introduction

Background

Public lands are essential sources of fresh water. Across the United States, about 180 million people rely on water originating from watersheds managed as public lands; in the Pacific Northwest the headwaters of many of these watersheds are managed by the National Park Service (USFS 2017). A defining characteristic of the national parks in the North Coast and Cascades Network (NCCN) is the high abundance of rivers and streams that support public uses, including recreational, commercial, and tribal fisheries; swimming and boating; and sources of water for human consumption. The waters of the NCCN also support habitat for five species of Federally Threatened fish and a variety of fish, amphibians, and insects that are “listed” by the states of Oregon and Washington (Table 1).

Due to their position in the landscape, these systems integrate the physical, chemical, and biological characteristics of the watersheds they drain. This puts them at an increased risk to a variety of environmental stressors and elevates the importance of monitoring these resources. To meet this need, NCCN developed a Water Quality Monitoring Program and protocol, which is focused on monitoring the wadeable streams in the NCCN that are the most at risk of water quality impairment (Rawhouser et al 2012). The protocol documented the decision-making processes to prioritize individual water bodies for monitoring, selecting sample sites, and selecting the parameters to monitor along with their associated methods.

The National Park Service (NPS) Inventory and Monitoring Program was established in 2000 to provide scientifically sound information on natural resources by documenting the status and long-term trends in the composition, structure, and function of park ecosystems and to determine how well current management practices are sustaining those ecosystems (Fancy et al. 2009). The Inventory and Monitoring Program is organized nationally around 32 networks including approximately 270 park units. The NCCN is composed of seven NPS units with natural resources: Ebey’s Landing National Historical Reserve (EBLA), Lewis and Clark National Historic Park (LEWI), Olympic National Park, North Cascades National Park and Mount Rainier National Park (Figure 1).



Figure 1. Map of the North Coast and Cascades Network.

Table 1. Federal and State status for listed aquatic species in the North Coast and Cascades Network.

Latin name	Common name	Federal status	WA status	OR status
<i>Ascaphus truei</i>	Tailed frog	None	Monitor	None
<i>Anaxyrus boreas</i>	Western toad	Species of Concern	Candidate	None
<i>Catostomus catostomus</i>	Salish Sucker and Longnose Sucker	None	Monitor	None
<i>Dicamptodon copei</i>	Cope's giant salamander	None	Monitor	None
<i>Plethodon dunni</i>	Dunn's salamander	None	Candidate	None
<i>Plethodon vandykei</i>	Van Dyke's salamander	Species of Concern	Candidate	None
<i>Rana cascadae</i>	Cascades frog	Species of Concern	Monitor	None
<i>Rana luteiventris</i>	Columbia spotted frog	None	Candidate	None
<i>Rhyacotriton cascadae</i>	Cascade torrent salamander	None	Candidate	None
<i>Rhyacotriton kezeri</i>	Columbia torrent salamander	Species of Concern	Monitor	None
<i>Rhyacotriton olympicus</i>	Olympic torrent salamander	Species of Concern	Monitor	None
<i>Cottus cognatus</i>	Slimy sculpin	None	Monitor	None
<i>Cottus gulosus</i>	Riffle sculpin	None	Monitor	None
<i>Cottus perplexus</i>	Reticulate sculpin	None	Monitor	None
<i>Lampetra ayresi</i>	River lamprey	Species of Concern	Candidate	None
<i>Lampetra richardsoni</i>	Western brook lamprey	Species of Concern	None	None
<i>Lampetra tridentata</i>	Pacific lamprey	Species of Concern	Monitor	None
<i>Novumbra hubbsi</i>	Olympic mudminnow	None	Sensitive	None
<i>Oncorhynchus keta</i>	Chum salmon (Hood Canal and Lower Columbia)	Threatened	Candidate	None
<i>Oncorhynchus kisutch</i>	Coho salmon (Lower Columbia and Southwest WA)	Candidate	None	Endangered
<i>Oncorhynchus mykiss</i>	Steelhead (Lower Columbia and Puget Sound)	Threatened	Candidate	None
<i>Oncorhynchus nerka</i>	Sockeye salmon (Ozette Lake)	Threatened	Candidate	None
<i>Oncorhynchus tshawytscha</i>	Chinook salmon (Puget Sound)	Threatened	Candidate	None
<i>Prosopium coulteri</i>	Pygmy whitefish	Species of Concern	Sensitive	None
<i>Salvelinus confluentus</i>	Bull trout (Coastal, Puget Sound and Columbia Basin)	Threatened	Candidate	None
<i>Thaleichthys pacificus</i>	Eulachon	None	Candidate	None
<i>Soliperla fenderi</i>	Fender's soliperlan stonefly	Species of Concern	None	None

Measurable Objectives

The measurable objectives for the NCCN Water Quality Monitoring Protocol are to:

- 1) Establish ranges in chemical and biological water quality parameters (water temperature, DO, specific conductance, pH, turbidity, benthic invertebrates and the presence of invasive species) within selected Wadeable streams and rivers in the NCCN and improve the understanding of the basic chemical, physical and biological processes that affect environmental quality of these surface waters.
- 2) Determine the status and trends in chemical and biological water quality parameters for selected Wadeable streams and rivers in the NCCN that are listed as impaired under section 303(d) of the CWA, and others that are at a high risk of impairment.
- 3) Determine if chemical and biological water quality parameters in NCCN water bodies, as indicated by the selected Wadeable rivers and streams, is in compliance with the state designated beneficial uses, or in acute or chronic exceedance of state standards.
- 4) Identify and detect new and emerging threats to water quality; including the point and non-point pollution sources within the watersheds affecting the water quality of NCCN water bodies.

This report presents ranges and summary statistics of the physical, chemical, and biological parameters measured during four field seasons from 2012 to 2015 from EBLA and LEWI. Pilot study data collected prior to 2012, as part of protocol development, will also be presented if they meet the guidelines and data quality standards of the final NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012).

Study Areas

Ebey's Landing National Historical Reserve

Designated by Congress in 1978, EBLA was the first historical reserve in the National Park System. It was designated “to preserve and protect a rural community which provides an unbroken historic record from 19th century exploration and settlement in Puget Sound to the present time.” The 25 square mile reserve is located in the Olympic Rain Shadow subdivision of the Puget Lowland Ecoregion in northwestern Washington State (Omernik 2010). It is a mixture of state, private, and federal lands, with the majority in private ownership. Agricultural and open space constitute 42% of the Reserve, woodlands comprise 36%, residential use accounts for 11.4%, wetlands occupy 5%, and urban and commercial uses constitute 1%. The climate is classified as moderate, receiving only 20 inches of precipitation annually (Baccus and Huff 2013).

Ebey's Watercourse

Ebey's Watercourse is the only stream sampled as part of the NCCN Water Quality Protocol at EBLA (Figure 2). The primary sources of water for Ebey's Watercourse are surface runoff of rain and ground water inflow. Small remnant amounts of wetlands found in the watershed likely help to recharge ground water inflow (Larrabee 2011). The 150 m long reach represents a 1st order intermittent stream occupying a single constrained channel that is severely incised into the surrounding terrace by steep banks greater than two meters high (Figure 3) (Strahler 1952).

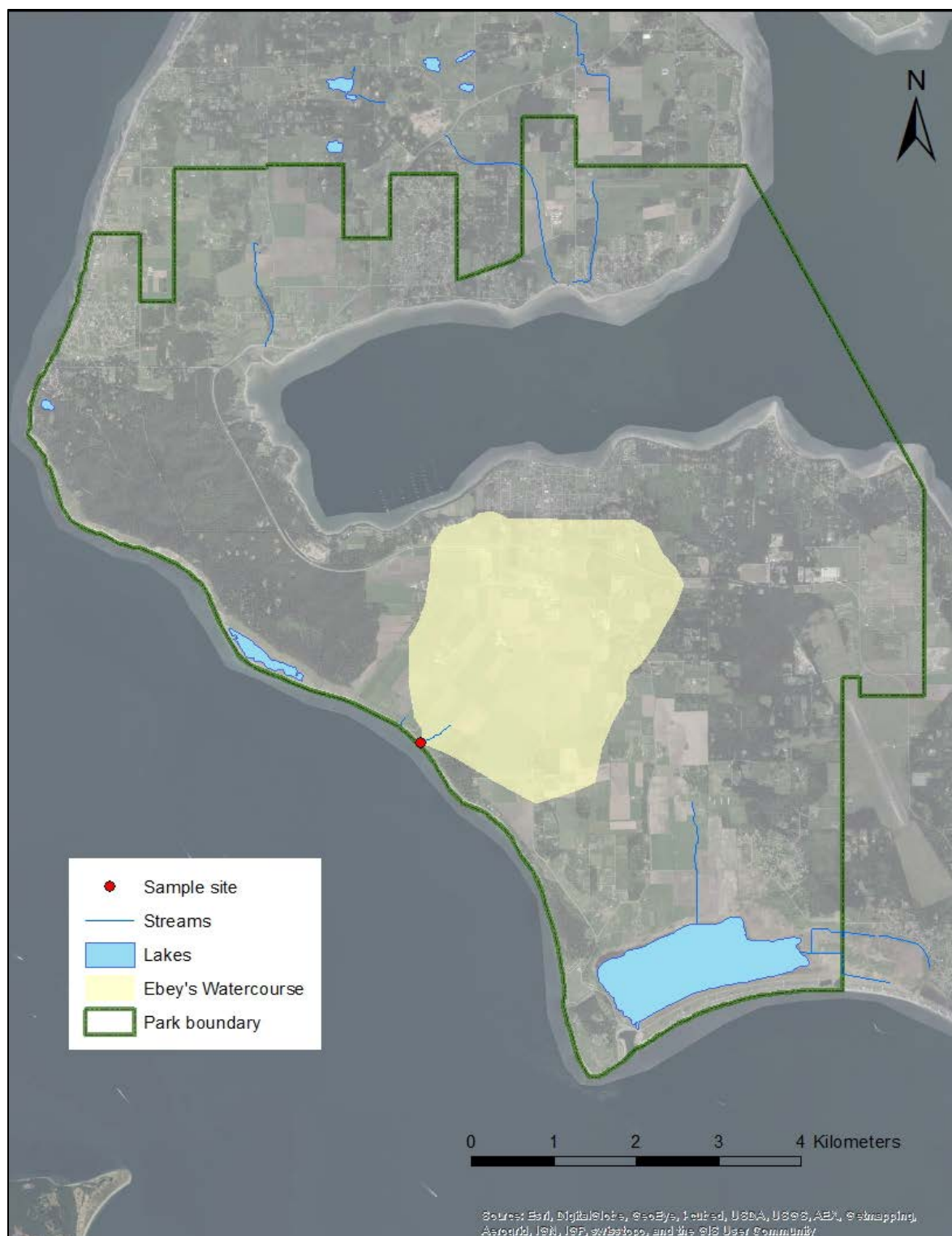


Figure 2. Map of the Ebey's Watercourse sample location and watershed in Ebey's Landing National Historic Reserve.



Figure 3. Looking upstream into the Ebey's Watercourse sample reach. The photograph, taken in 2012, is representative of the habitat throughout the sample reach depicting the steep banks and highly constrained channel.

The majority of the watershed is privately owned and has been significantly modified by human activity. Several small isolated holdings are managed by the NPS. Land use within the Ebey's Watercourse watershed includes rural residential development, agriculture, mining and recreation. Vegetation in the watershed is composed of mixed forest, coastal coniferous forest, restored natural grassland, as well as agricultural lands used for crop production and pasture (Larrabee 2011). Ebey's Watercourse was selected for monitoring because it is the only freshwater stream resource within EBLA and because it is heavily influenced by human activity (Welch and Rawhouser 2017).

Lewis and Clark National Historical Park

Originally established in 1962 as Fort Clatsop National Memorial, consisting of 125.2 acres, LEWI has expanded to over 3,500 acres, scattered across 40 miles of the Pacific coast (Figure 4). The Park complex incorporates 12 separate units spread across the Coast Ecoregion (Omernik 2010). Habitats range from estuarine mudflats and tidal marshes, to shrub and forested swamps and upland coniferous rainforest, dominated by Sitka spruce (*Picea sitchensis*). Nearly a quarter of LEWI is comprised of wetlands (Rawhouser et al. 2012).

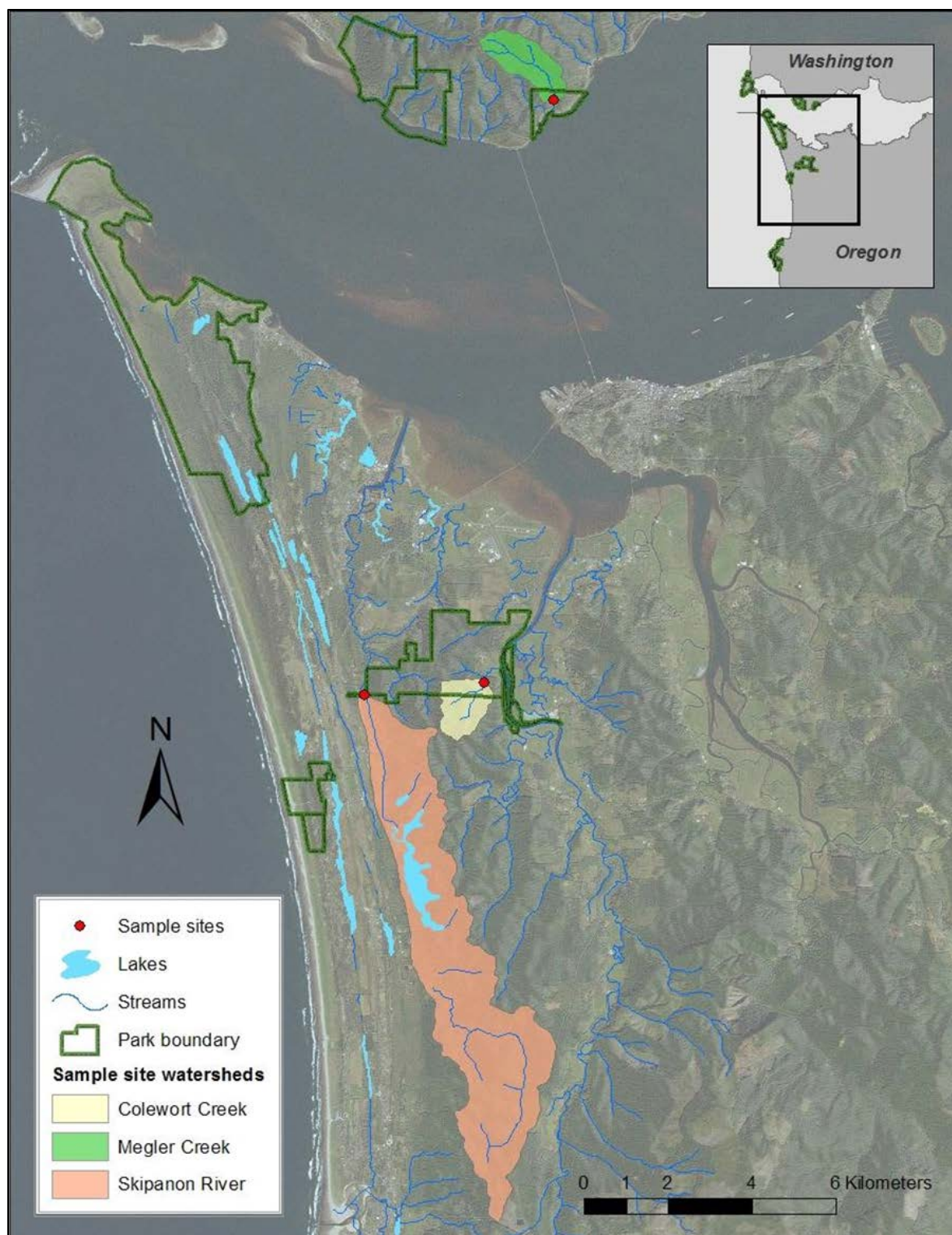


Figure 4. Map of the sample locations and associated watersheds in Lewis and Clark National Historic Park.

Other water resources consist of the Lewis and Clark and Skipanon Rivers, low-gradient brackish sloughs, freshwater ponds, and several small streams and springs. The park is affected by adjacent land-use including forest harvest, urban development, and water withdrawals from the Skipanon and Lewis and Clark Rivers. Three sites are sampled at LEWI as part of the NCCN Water Quality Protocol: the Skipanon River, Colewort Creek, and Megler Creek.

Skipanon River

The Skipanon River is a tidally influenced river located in Oregon State that flows into Young's Bay on the Columbia River (Figure 4). The sample reach in the Skipanon River is a 2nd order stream (Strahler 1952) that occupies a single channel that is highly constrained by incision within a coastal plain. Surface runoff from rain and ground water inflow primarily feed the Skipanon River. While the water levels in the sample reach vary with the tides, no saltwater intrusion to the sample reach is evident at this time (Figure 5).



Figure 5. Looking downstream from the footbridge, located in the middle of the sample reach, into the Skipanon River in 2012. The low water levels and exposed banks are typical of conditions during low tide. The cover photograph depicts the habitat conditions upstream of this point during high tide.

The only NPS land within the Skipanon River watershed consists of a trail right-of-way that is approximately 200 m long, which is also the location of the sample reach (Figure 4). Human activity within the watershed consists of commercial forestry, agriculture, rural development, and recreational use (Welch and Rawhouser 2017). Up to 25 species of fish and amphibians potentially

inhabit the Skipanon River (Welch and Rawhouser 2017). The Oregon's Department of Environmental Quality (DEQ) (DEQ 2015) has flagged the Skipanon River for concern due to alkalinity and chloride levels and has listed this reach as a 303(d) waterbody for dissolved oxygen impairment.

Colewort Creek

Colewort Creek is a small perennial stream located in Oregon State that drains into the Lewis and Clark River (Figure 4). The 150 m long sample reach represents a 2nd order stream (Strahler 1952) occupying a single channel located in an unconstrained broad valley (Figure 6).



Figure 6. Looking upstream from the start of the Colewort Creek sample reach. The photograph, taken in 2012, depicts the unconstrained channel and vegetative cover representative of the sample reach.

Roughly 35% of the Colewort Creek watershed is managed by the NPS and the remaining land is privately owned. Human activity within the watershed consists of commercial forestry and recreational use. Colewort Creek was selected for monitoring because of the high road density within its watershed and active commercial forest activities. Colewort Creek supports up to nineteen fish species, and nine amphibian species (Welch and Rawhouser 2017).

Megler Creek

Megler Creek is a small perennial stream located in Washington State that drains into the Columbia River (Figure 4). The 150 m long sample reach represents a 2nd order stream (Strahler 1952) occupying a single channel that is minimally constrained within its floodplain by debris aprons (Figure 7). Roughly 20% of the Megler Creek watershed is managed by the NPS and the remaining land is privately owned and managed for commercial forestry. Concern about the potential effects of commercial forest management activities on Critical Habitat for Endangered Chinook salmon (*Oncorhynchus tshawytscha*), and lack of information regarding biological resources in this location, are the primary reason for selecting this location for monitoring (Welch and Rawhouser 2017).



Figure 7. Looking upstream from the top of the Megler Creek sample reach in 2012. The conditions pictured are representative of the habitat conditions throughout the sample reach.

Methods

Target Population and Sample Design

Data in this report were collected over a four-year period from July 2012 to August 2015 from a target population of the streams and rivers within each park that were identified as being at the highest risk of impairment. Within each of these water bodies a permanent sample reach was established to serve as a benchmarked location for future monitoring and each reach was sampled once a year on an annual basis during a specific index period. The EBLA index period occurs in early May and the LEWI index period occurs from late July to early August. To control for seasonal and diurnal variability, all field data were collected within a ten-day sample window of the initial sample event between 10:00 am and 2:00 pm.

Data Collection

A series of 18 parameters intended to characterize the chemical, physical, and biological attributes of the sample reach were collected during each sample event following standard operating procedures (SOP) documented in the NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012) (Table 2).

Table 2. Chemical, physical, and biological parameters collected on an annual basis as part of the NCCN water quality monitoring program. Full descriptions of the methods used are detailed in the NCCN Water Quality Monitoring Protocol; the associated SOP is listed as a reference to aid the reader (Rawhouser et al. 2012).

Attribute	Parameter	Field Method
Water Chemistry and Quality	Odors and Films	Qualitative observations of water clarity, water odor, sediment odor, and surface films (NCCN SOP 6, USEPA 2004).
	Instantaneous Temperature, DO, Specific Conductance, and pH	Seven separate measurements are collected at the downstream end of the sample reach in a well-mixed location using a Hach HQD multi-parameter digital meter.
	Turbidity	Seven replicate samples per parameter are collected at the downstream end of the reach in a well-mixed location and measured on site using a Hach 2100Q portable turbidity meter.
	Continuous Temperature	Measurements are made with HOBO® Pro v2 temperature loggers set to record every 60 minutes on a year-round basis. Loggers are installed in the wetted channel in a well-mixed location of the sample reach and an air temperature logger is installed 3 to 10 feet from the wetted channel adjacent to the water temperature logger.
Physical Habitat	Wetted Width	Measured at 10 equally spaced locations, from a random start, along the length of the sample reach using a laser range finder.
	Bankfull Width	Measured at 3 equally spaced locations along the length of the sample reach using laser range finder. Measurement locations are selected based on the presence of definitive bankfull indicators.
	Thalweg Depth	Measured at 10 equally spaced locations along the length of the sample reach using a stadia rod. Measurements are concurrent with wetted width is measurements.

Table 2 (continued). Chemical, physical, and biological parameters collected on an annual basis as part of the NCCN water quality monitoring program. Full descriptions of the methods used are detailed in the NCCN Water Quality Monitoring Protocol; the associated SOP is listed as a reference to aid the reader (Rawhouser et al. 2012).

Attribute	Parameter	Field Method
Physical Habitat (continued)	Channel Constraint, Torrent and Flooding Evidence	Qualitative assessment made within the sample reach (NCCN SOP 11, USEPA 2004).
	Human Influence	Qualitative assessment of stream channel and riparian habitat within 20 m of the bankfull channel edge (NCCN SOP 11, USEPA 2004).
	Qualitative Rapid Habitat Assessment	Qualitative assessment made from observations throughout the sample reach (NCCN SOP 11, USEPA 2004).
Biological	Invasive Plants	Field observations made within 10 m of the bankfull channel edge (SOP 10).
	Invasive Animals	Field observations made in and along the wetted edge of the stream channel (SOP 10).
	Benthic Macroinvertebrates	Composite of four randomly located 2-square foot samples collected from riffle habitat (NCCN SOP 8, Hayslip 2007).

Quality Assurance and Control

Measures of precision, accuracy, bias, sensitivity, and completeness (Tables 3 and 4) were calculated for applicable data according to the quality assurance objectives described in the Data Quality Assurance and Control Plan which are outline in SOPs 7, 9, and 15 of the NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012). The quality assurance and control results, as measurement quality objectives (MQO), are reported in Appendix A of this report.

Table 3. Descriptions of data quality indicators for each of the measured parameters used to support the data quality objectives established for the NCCN Water Quality Monitoring Project.

Data Quality Objective	Parameter	Description of Data Quality Indicator
Precision	Instantaneous Temperature, DO, Specific Conductance, pH, and Turbidity	Measured as the RPD using the first and last measurements for all the water chemistry parameters collected during a sample event.
	Continuous Temperature	Measured as RPD using consecutive measurements recorded by the water temperature data logger during instrument calibration.
	BMI	Measured as RPD using metric values generated from replicate BMI samples collected from the same stream during the same sample event. Conducted for at least 10% of the sites sampled on an annual basis. Due to small sample size, this will be assessed in the 5-year reports.
	Wetted Width, Bankfull Width, and Thalweg Depth	Measured as the RPD using two measurements made by different people in the same location of the stream during the same sample event.

Table 3 (continued). Descriptions of data quality indicators for each of the measured parameters used to support the data quality objectives established for the NCCN Water Quality Monitoring Project.

Data Quality Objective	Parameter	Description of Data Quality Indicator
Accuracy and Bias	Instantaneous Temperature, DO, Specific Conductance, pH, and Turbidity	Measured as the Percent Difference (PD) between a measured value and an expected result using a calibration standard. This is completed before an instrument is used in the field (immediately after calibration) and after it has been used in the field. Instantaneous temperature is measured similar to continuous temperature.
	Continuous Temperature	Measured as the Absolute Value Difference, during instrument calibration, by comparison of a series of two values, one of which is an expected value and the other as the measured result.
	BMI	Will be assessed using published scientific literature and government reports and will be addressed in the 5-year reports.
	Wetted Width, Bankfull Width, and Thalweg Depth	For width measurements (laser range finder), this is measured as the PD between two values one of which is a known length. Accuracy and bias are not determined for thalweg measurements.
Sensitivity	Instantaneous Temperature, DO, Specific Conductance, pH, and Turbidity	Measured as Alternate Measurement Sensitivity (AMS) using seven consecutive measurements collected from a stream during the same sample event, once at the beginning of the field season, and once at the end of the field season.
	Continuous Temperature	Measured as AMS using seven consecutive measurements collected during instrument calibration, before deployment into the field and after being returned from the field.
	BMI	Will be assessed using published scientific literature and government reports and will be addressed in the 5-year reports.
	Wetted Width, Bankfull Width, and Thalweg Depth	NA
Completeness	All Parameters	Completeness will be addressed in 5-year summary reports; however, data gaps will noted in annual reports.
Representativeness	All Parameters	Changes in data collection methods or laboratories conducting invertebrate taxonomy will be noted in annual reports when they occur.
Comparability	All Parameters	Comparability will be addressed in 5-year summary reports; however, data gaps will noted in annual reports.

Table 4 (continued). Measurement quality objectives acceptance/rejection criteria for each of the measured values. TBD = criteria to be determined with additional years of data collection. NA = Not applicable.

Parameter	Precision (RPD)	Accuracy and Bias(PD)	Sensitivity (AMS)
Temperature	≤10	≤0.2	TBD
DO	≤10	± 10 (0 to 8 mg/L), ± 20 (>8 mg/L)	TBD

Table 4. Measurement quality objectives acceptance/rejection criteria for each of the measured values. TBD = criteria to be determined with additional years of data collection. NA = Not applicable.

Parameter	Precision (RPD)	Accuracy and Bias(PD)	Sensitivity (AMS)
Specific Conductance	≤10	± 10	TBD
pH	≤10	± 10	TBD
Turbidity	≤10	± 10	TBD
Continuous Temperature	≤10	≤0.2 (Water), ≤0.4 (Air)	TBD
BMI	<40	TBD	TBD
Wetted Width	≤10	± 10	NA
Bankfull Width	≤10	± 10	NA
Thalweg Depth	≤10	NA	NA

Accuracy and bias of instantaneous measurements were assessed against NIST traceable standards and thermometers before and after each sample event, and again at the beginning and end of the field season. Continuous water temperature measurements were only assessed before and after each deployment of the data loggers, typically every four years, against an NIST traceable thermometer.

Continuous temperature data also required additional quality assurance and control procedures that were not part of the original Data Quality Assurance and Control Plan of the NCCN Water Quality Monitoring Protocol. These procedures included congruently graphing the air and water temperature data to identify and flag anomalies in the water temperature data that were not representative of well mixed water. For example, this process was used to identify periods of time when the water temperature loggers were exposed to air, suspended in shallow poorly mixed water, or were buried in sediment. Flagged data were evaluated with more detail by reviewing the deployment and retrieval pictures of the site, comparing water temperature data to flow data (when available), comparing against data from previous years and nearby temperature stations, and assessing the correlation of air and water temperature data for the dates of concern (Sowder and Steel 2012, Toohey et al. 2014). We summarized the amount of flagged or missing data and removed the flagged data before conducting any analysis when they did not meet the data quality objectives. Summaries of continuous water temperatures were only completed for time periods with more than a 90% complete temperature record (Rawhouser et al. 2012). When possible, corrections will be applied to flagged data so it can be used for analysis in 5-year reports.

Qualitative and observational parameters including odors and films, channel constraint, torrent evidence, flooding evidence, the amount of human influence, the rapid habitat assessment, and observations of invasive species do not have quantifiable data quality objectives. However, to insure the consistency of these data, field crews reviewed the standard operating procedures with the project lead during annual training and observations are verified by at least two trained crewmembers during data collection.

Data Summarization

Data were summarized according to water year, which is defined by the U.S. Geological Survey (USGS) as the 12-month period from October 1 through September 30, of the following year (Figure 8). The water year is designated by the calendar year in which it ends and includes nine of the twelve months of data from that year and three months of data from the previous calendar year (USGS 2015). The seasonal obligations for this summary were determined using seasonal equinoxes and solstices, and applying each month to the season in which the majority of its days fall (Figure 8.) For example, the winter solstice typically occurs near December 21th, therefore the majority of December days fall in the season prior, and December is designated as Fall.

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Water Year	Starts Oct. 1st									Ends Sept. 31st		
Season	Fall			Winter			Spring			Summer		

Figure 8. Figure illustrating the relationship of the calendar months to the water year and seasons used to summarize the continuous temperature data.

Instantaneous Water Chemistry and Continuous Water Temperature

Instantaneous data for temperature, DO, specific conductance, and turbidity were summarized and reported as mean values for each index period. Because pH is a log transformed value, it was summarized as a median value. These data can indicate if a stream does not meet the CWA standards established for Washington and Oregon States (Table 5). Due to their instantaneous nature (one time grab vs. multiple measurements over an extended period) they should not be interpreted to indicate that a given stream is fully compliant with CWA standards outside of the index period. However, since the index period for these streams occurs during base flow periods when DO is typically at the lowest levels, measurements of DO are likely providing adequate information to alert managers about potential issues related to this parameter.

Continuous temperature data were summarized according to water year, using box plots to compare the monthly distribution of stream temperatures within a reach (Figure 4). To determine if a stream was meeting CWA standards the highest 7-day moving average of daily maximum temperature was calculated and compared to the water quality criterion for the designated beneficial use of the stream (Table 5) (DEQ, 2017, DOE, 2016, Rawhouser et al. 2012). Plots of the 7-day moving average of daily maximum temperature over time were also generated to provide a context for the duration and frequency of any exceedances.

Table 5. Washington and Oregon State designated beneficial uses and water quality criteria established to meet Clean Water Act standards.

Sample Location	Aquatic Life Use Designation	Temperature (7-day Average Maximum)	Dissolved Oxygen	pH	Turbidity (background of >50 NTU)
EBLA ¹	Salmonid spawning, rearing and migration; and Core summer salmonid habitat	16.0 °C	8.0 mg/L ³	6.5 to 8.5	Not to exceed 5 NTU over background
Skipanon River ²	Salmon/steelhead spawning use (Oct. 15th to May 15th)	13.0 °C	11.0 mg/L ⁴	6.5 to 8.5	Not to exceed 10% over background
	Salmon and trout rearing and migration (year-round)	18.0 °C	8.0 mg/L ⁴		
Colewort Creek ^{2,5}	Salmon and trout rearing and migration	18.0 °C	8.0 mg/L ⁴	6.5 to 8.5	Not to exceed 10% over background
Megler Creek ¹	Salmonid spawning, rearing and migration; and Core summer salmonid habitat	16.0 °C	8.0 mg/L ³	6.5 to 8.5	Not to exceed 5 NTU over background

¹ Washington State (DOE, 2016).

² Oregon State DEQ, Skipanon River and Colewort Creek are classified as cold water, as described in, Table 21 of the Oregon department of environmental quality water quality standards (DEQ, 2017).

³ Lowest 1-day minimum (DOE, 2016)

⁴ Absolute minimum criterion are applied here because only one day of sampling for DO is conducted. (DEQ, 2017).

⁵ Recent restoration efforts in Colewort Creek have resulted in adult salmon returning to the creek. Reevaluation of this location in future years will likely result in salmon/steelhead spawning use designation (Chris Clatterbuck, LEWI Chief of Resources, email communication, 04-20-2017).

Habitat Data

Physical habitat data for wetted width, bankfull width, thalweg depth and the rapid habitat assessment data were summarized using basic descriptive statistics. Measurements for wetted width, bankfull width and thalweg depth were summarized as minimum, maximum and mean measurements. The rapid habitat assessment evaluates ten components considered indicative of the habitat conditions for a stream (USEPA 2004). When summed, these scores range from 0 to 200 and provide an overall assessment of the habitat conditions in the sample reach with higher scores representing more favorable conditions for native organisms.

Biological Data

Invasive Plants and Animals

Data about invasive plants and vertebrate animals are primarily qualitative and are intended to document presence. However, information on these species was summarized based on estimates of abundance and the extent of the area that was influenced with the intent of providing managers a rough sense about changes over time. Data about invasive invertebrate species were summarized with the benthic invertebrate data described below.

Benthic Macroinvertebrates

Analysis of benthic macroinvertebrate (BMI) data was completed using a standardized sample based on a consistent level of taxonomic effort that was applied among all samples within a park. This was achieved by removing the count data for taxa with ambiguous identifications following the guidance of Cuffney et al. (2007). Specifically, data for ambiguous parent taxa were removed if the sum of the children's abundances was greater than the parent's abundance. Or, if the children taxa had a lower abundance than the parent taxa these taxa were merged with the parent taxa (Table 6). After standardizing the taxonomic resolution, each sample was randomly sub-sampled without replacement to a count of 300 organisms and all analysis was conducted using the 300-count sample.

Table 6. A hypothetical example of how the taxonomic effort for the benthic macroinvertebrate data was standardized (Adapted from Hubler 2008).

Initial Identification	Taxonomic Level	Original Abundance	Action	Final Operational Taxonomic Unit	Final Abundance
Baetidae	Family	7	Exclude	Drop	–
<i>Baetis</i>	Genus	132	None	<i>Baetis</i>	150
<i>Baetis tricaudatus</i>	Species	13	Aggregate to genus	<i>Baetis</i>	–
<i>Baetis bicaudatus</i>	Species	2	Aggregate to genus	<i>Baetis</i>	–
<i>Baetis alius</i>	Species	3	Aggregate to genus	<i>Baetis</i>	–
<i>Acentrella</i>	Genus	15	None	<i>Acentrella</i>	15
<i>Dipheter hageni</i>	Species	4	None	<i>Dipheter hageni</i>	4

After standardization, we summarized the BMI data according to nine different measures or metrics (Table 7). For this report, we selected metrics that were widely used in other monitoring programs and that would provide a means to assess the over-all ecological condition of a stream and provide information to help identify sources of environmental stress.

Table 7. Summary statistics and indicator metrics for benthic macroinvertebrate samples.

Metric Name (Acronym)	Description	Applicable Sites
Richness (R)	Number of standardized taxonomic units in a sample. Usually determined at the genus or species level.	All sites
Diversity (D)	Measured as Simpson's Index of Diversity (D) calculated as $D = 1 - (\sum p_i^2)$ where p_i is the proportional abundance of taxa i .	All sites
Taxonomic Completeness (OE score)	Describes the ratio of taxa that are expected to occur at a site compared to the taxa that are collected or observed at a site, commonly referred to as an OE score. OE scores were calculated using two models: PREDATOR (Hubler 2008) and West-wide (Miller 2016).	Ebey's Watercourse (West-wide) Megler Creek (PREDATOR) Colewort Creek (PREDATOR)

Table 7 (continued). Summary statistics and indicator metrics for benthic macroinvertebrate samples.

Metric Name (Acronym)	Description	Applicable Sites
Temperature Tolerance Index (TI)	Calculated as the weighted average of temperature tolerance values for the taxa collected in a sample using tolerance values established by the USEPA for the Western United States (Yuan 2006). Taxa without established tolerance values were omitted from the calculation.	All sites
Fine Sediment Tolerance Index (FSI)	Calculated as the weighted average of fine sediment tolerance values for the taxa collected in a sample using tolerance values established by the United States Environmental Protection Agency for the Western United States (Yuan 2006). Taxa without established tolerance values were omitted from the calculation.	All sites
Metals Tolerance Index (MTI)	Calculated as the weighted average of metals tolerance values for the taxa collected in a sample using tolerance values established for taxa in the Clark Fork River in Idaho (McGuire 2009). Taxa without established tolerance values were omitted from the calculation.	All sites
Nutrient Tolerance Index (NI)	Calculated as the weighted average of nutrient tolerance values for the taxa collected in a sample using tolerance values established by the USGS for the contiguous United States (Carlisle et al. 2007). Taxa without established tolerance values were omitted from the calculation.	All sites

Richness and diversity of the BMI assemblage were calculated due to their widespread use as ecological indicators and to provide the reader with some context when evaluating the metrics for taxonomic completeness and tolerance to temperature, fine sediment, metals, and nutrients (Barbour et al. 1999). We used Simpson's Index as a measure of diversity because it provided a simple means of assessing the relative abundance of the taxa in a sample. The Simpson Index ranges in value from 0 to 1 and measures the probability that two randomly chosen organisms from a sample will represent the same taxa, thus lower values indicate a greater diversity of taxa in the sample.

Measures of taxonomic completeness are used to predict what taxa are expected to occur in a sample given a set of environmental factors such as the elevation of the stream, the total amount of precipitation that falls in the watershed, and/or the watershed's surficial geology. The statistical models used to assess taxonomic completeness are often referred to as RIVPACS models. The results of these models allow the practitioner to compare the taxa that are collected (observed) to what is expected to be present. This is termed the observed to expected ratio (OE score) which ranges from 0 to 1. Values close to 0 are considered to be in poor condition because they are missing taxa that are expected to occur in the sample, and values close to 1 are considered to be in good condition because they are more taxonomically complete. A large and well-established body of literature has been developed for RIVPACS models and an excellent tutorial can be accessed online at the Western Center for Monitoring and Assessment of Freshwater Ecosystems (WCMA 2017). We used two models, the first, PREDATOR was developed by the Oregon State DEQ for the Marine Coastal Forest Ecoregion (Hubler 2008) and the other, West-wide, was developed by Utah State University for the EPA for the Western United States.

Index based metrics were calculated as the weighted average of the combined tolerance values for all of the organisms in the standardized sample. The tolerance values for a taxon are a single number that represents a taxa's relationship to an environmental gradient such as water temperature, fine sediment, as well as metal and nutrient concentrations. The tolerance values we used consisted of two basic types. The first set was developed by Yuan (2008) for temperature and fine sediment and were established using the weighted average of the temperature or percent contribution of fine sediment to the benthos of a stream where a taxon is expected to occur. For example, a taxon with a temperature tolerance value of fifteen is expected to be found in streams where water temperatures average 15°C during the daylight hours of the base flow period. In turn, the temperature tolerance index (TI) calculated for a stream, using the weighted average of the tolerance values for the taxa found in that stream, should represent the average water temperature for that stream. The other basic set of tolerance values, those for nutrient and metal concentrations, use an ordinal scale that ranges from one to ten and taxa with higher values are more tolerant to higher levels of either nutrients or metals. The usefulness of metrics represented by ordinal scale values is increased when they can be compared to a specific ecological condition. At this time, these thresholds have not been established for the streams of the NCCN. However, these values can be compared over time and between streams within a park unit.

We selected tolerance values that would be the most applicable to the streams in the NCCN, however, research related to refining tolerance values is an active area of science and future reports may use different values if they are more applicable to the streams being assessed or increase the sensitivity of the metric.

At this time, none of the measures has established values for classifying the condition of a stream in terms of meeting numeric CWA standards in Washington and Oregon. We included them in this report to help provide a context about how the BMI assemblages change over time, allow comparisons with previously published biological assessments, and provide managers with information about the biological response to changes in stream temperature and chemistry.

Results

Ebey's Landing National Historic Reserve

Water Chemistry and Turbidity

Ebey's Watercourse was dry during the August 22, 2012 field visit. We adjusted the index period to conduct the sampling by the second week of May when we expected the stream to have water on an annual basis. Subsequent data collection occurred on May 15, 21, and 20 of 2013, 2014, and 2015 respectively. During all of these visits Ebey's Watercourse contained water and met the CWA standards for DO and pH (Tables 5 and 8). Background turbidity levels for Ebey's Watercourse have not been established, therefore, determining compliance with CWA standards was not possible for this parameter. All of the instantaneous water chemistry and turbidity measurements collected from Ebey's Watercourse met the MQO (Appendix A).

Table 8. Mean and standard deviation (SD) values for instantaneous water chemistry measurements (n=7) made in Ebey's Watercourse from 2013 to 2015.

Parameter	2012	2013 (SD)	2014 (SD)	2015 (SD)
Temperature (C°)	Dry	11.80 (0)	13.10 (0)	13.01 (0.04)
Dissolved Oxygen (mg/L)	Dry	10.02 (0.01)	10.02 (0.01)	9.75 (0.02)
Specific Conductance (µS/cm)	Dry	1692 (7.27)	1381 (0.53)	1945 (0.79)
pH*	Dry	8.13 (0.02)	8.36 (0.04)	8.33 (0.01)
Turbidity (NTUs)	Dry	16.76 (0.46)	2.95 (0.39)	2.14 (0.56)

*Median reported for pH.

Continuous Temperature Data

Ebey's watercourse is an intermittent stream and the continuous temperature data revealed that it dewatered for 89 days in 2013 and 95 days in 2014 (Table 9 and Figure 9). The stream did not dewater in 2015; however, the water temperatures during this period were higher than previous years for several months (Figures 10 and 11). The A7DMT exceeded the CWA standard of 16.0°C for fifteen days during 2015 (Figure 12).

The Ebey's Watercourse continuous temperature data represents a unique situation where the dewatering of the water logger coincides with subsidence of the flow in the sample reach. This assessment is supported by previous research conducted on the hydrology of this system (Larrabee 2011) and due to the highly confined nature of the sample reach and small size of the wetted channel (Figure 9). None of the data gaps was attributed to equipment malfunction and all of the continuous temperature loggers deployed at EBLA met the MQO (Appendix A).

Table 9. Periods with gaps in continuous water temperature measurements or when measurements were flagged and excluded from analysis.

Water Year	Start Date	End Date	Notes	Flagged Data	
				# Days	% of Year
2013	10/1/2012	5/15/2013	Logger installed 5/15/2013	226	86
	7/1/2013	9/27/2013	Exposed to air	89	86
2014	10/1/2013	1/4/2014	Exposed to air	95	26



Figure 9. The position of the air (red circle) and water (blue circle) loggers as they were deployed in Ebey's Watercourse in 2013 (left), and the water logger as it was found during the 2014 site visit (right). Note: The gray cowlings holding the temperature loggers are 5 cm in diameter and 20 cm in length.

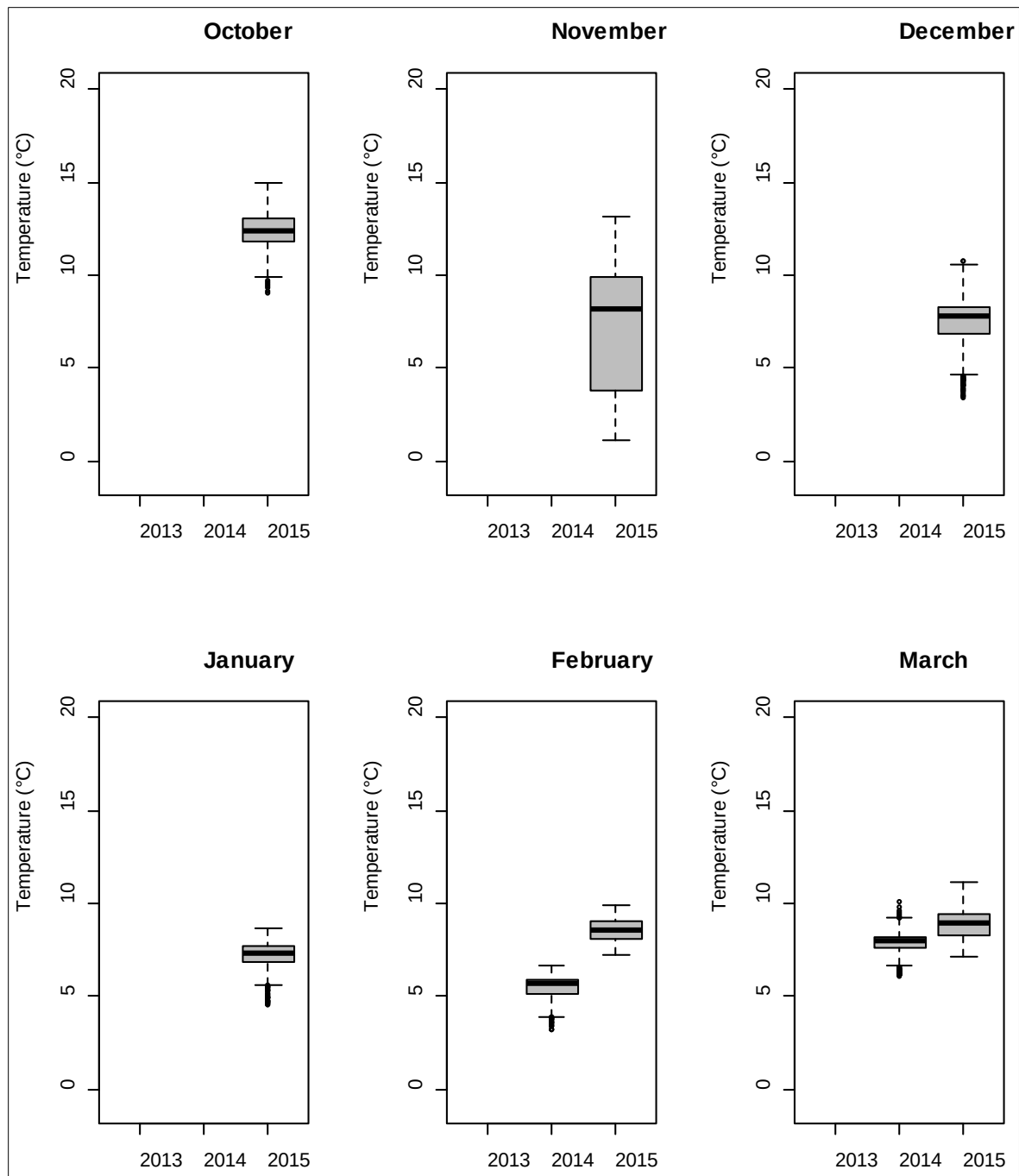


Figure 10. Box plots comparing the monthly distribution of hourly continuous water temperature measurements made in Ebey's Watercourse for water years 2013 to 2015 (October through March). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper "Ts". Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by open circles.

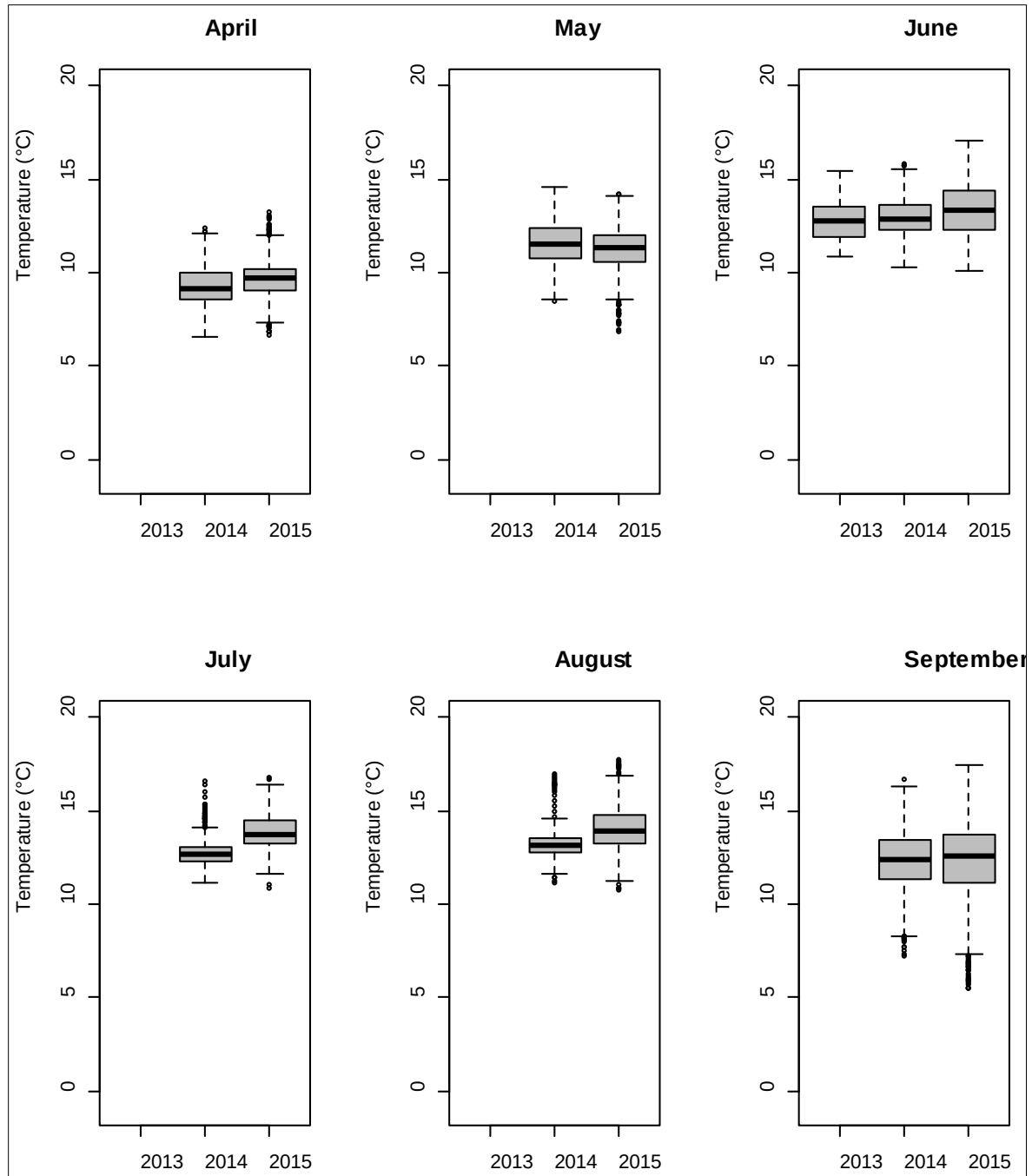


Figure 11. Box plots comparing the monthly distribution of hourly continuous water temperature measurements made in Ebey's Watercourse for water years 2013 to 2015 (April through September). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper "Ts". Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by open circles.

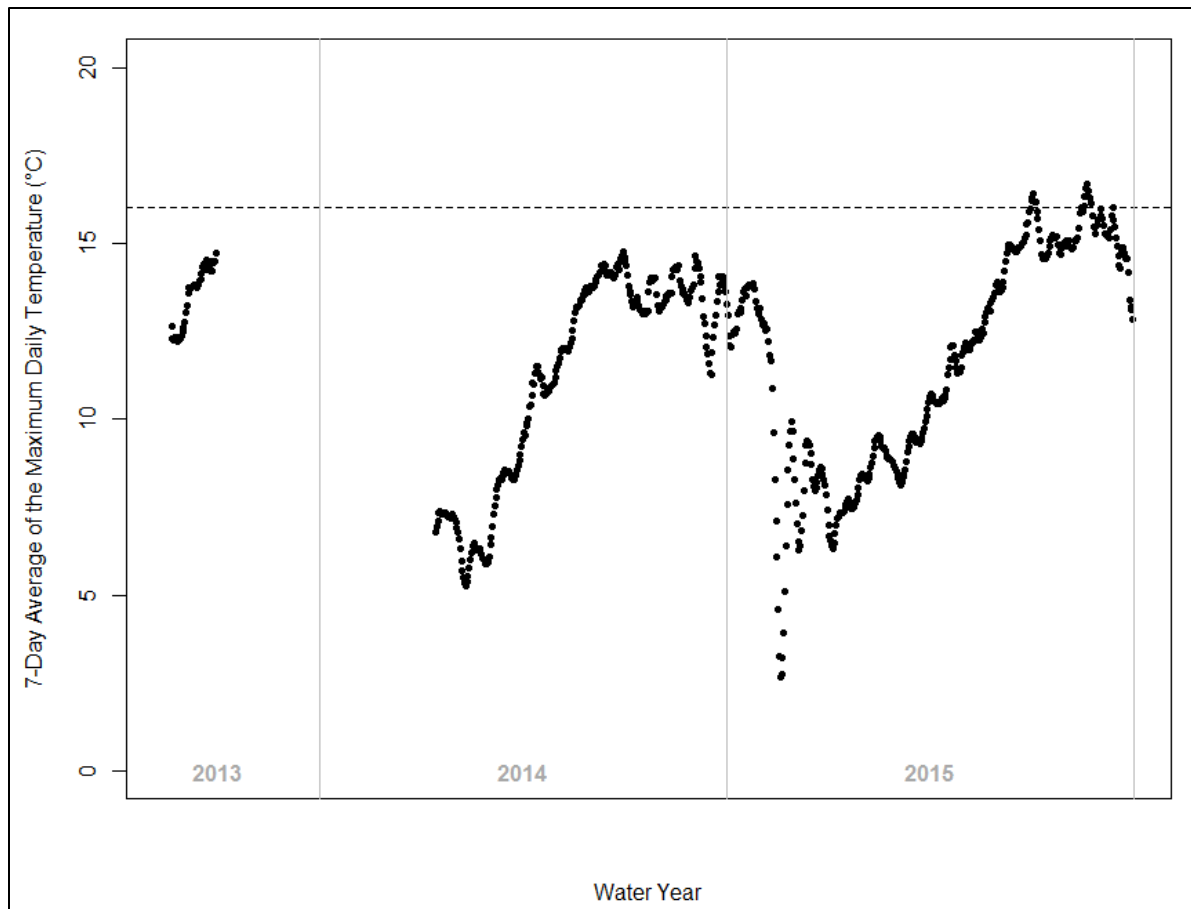


Figure 12. A scatter plot of the A7DMT in Ebey’s Watercourse from 2013 to 2015. The A7DMT exceeded the 16.0 °C (dashed line) criterion for fifteen days during the 2015 water year.

Stream Habitat

Wetted width, bankfull width and thalweg depths remained consistent from 2013 to 2015 (Table 10). While 2015 had the highest Rapid Habitat Assessment score out of the three years it was sampled, this score still reflects poor conditions in the Ebey’s Watercourse sample reach (Table 10).

Table 10. EBLA Rapid Habitat Assessment and physical habitat measurements from 2013 to 2015.

Year	Wetted Width (m), n=10			Bankfull Width (m), n=3			Thalweg Depth (m), n=10			Rapid Habitat Assessment
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Sum
2013	0.2	1.6	0.8	1.4	2.0	1.7	0.02	0.09	0.06	35
2014	0.3	1.8	0.7	2.0	2.4	2.1	0.04	0.11	0.07	40
2015	0.3	0.7	0.5	1.3	2.6	2.0	0.01	0.05	0.03	60

Invasive Plants and Animals

Four invasive plant species have been observed in the Ebey's Watercourse sample reach since monitoring was initiated in 2012 (Table 11). However, invasive plants were not detected during the 2015 surveys.

Table 11. Non-native and invasive species observed in and adjacent to Ebey's Watercourse during field visits from 2012 to 2015.

Year	Invasive Species	Estimated Abundance	Estimated Area of Influence (m ²)
2012	Reed canary grass (<i>Phalaris arundinacea</i>)	>100 Stems	>50
	Himalayan blackberry (<i>Rubus bifrons</i>)	>100 Stems	>50
2013	Poisonous hemlock (<i>Conium maculatum</i>)	>100 Stems	>50
2014	Himalayan blackberry (<i>Rubus bifrons</i>)	>100 Stems	>50
	Fathead minnow (<i>Pimephales promelas</i>)	5	NA

Benthic Macroinvertebrates

Eleven taxa were collected from Ebey's Watercourse in 2015, represented entirely by Diptera, also known as flies, and non-insect taxa (Table 12). While richness decreased each year, the number of taxa that was expected to occur in a sample under reference conditions increased, indicating a potential improvement in water quality and habitat conditions (Table 12). The remaining index values showed little change and should be interpreted with caution since a large percentage of the organisms in the samples did not have established tolerance values. However, the TI values did agree with the instantaneous temperature measurements (Table 8) which lends some confidence to the TI scores.

Table 12. Metric values for the biological condition of Ebey's Watercourse for samples collected from 2013 to 2015. Numbers in parentheses indicate the percent of the organisms in the sample that did not have assigned tolerance values.

Year	Richness (R)	Diversity (D)	Taxonomic Completeness (O/E)	Temperature Index (TI)	Fine Sediment Index (FSI)	Metal Tolerance Index (MTI)	Nutrient Index (NI)
2013	14	0.76	0.34	13(60)	22(60)	7.1(59)	4.4(60)
2014	13	0.74	0.45	13(71)	22(71)	4.0(71)	5.9(71)
2015	11	0.74	0.56	13(47)	22(47)	5.7(47)	4.4(47)

Incidental Observations

Field crews documented the presence of several non-native fathead minnows (*Pimephales promelas*) and a single native adult Northern red-legged frog (*Rana aurora*) during the 2014 site visit. However, neither of these species was observed during the 2015 field visit (Figure 13).



Figure 13. Photographs of a non-native fathead minnow (left) and a native adult red-legged frog (right), observed in Ebey's Watercourse during the 2014 site visit.

Lewis and Clark National Historical Park

Water Chemistry and Turbidity

All of the sample reaches in LEWI met CWA standards for DO and pH with the exception of the Skipanon River which consistently had DO concentrations below the 8.0 mg/L criterion, failing to meet CWA standards from 2012 to 2015 (Table 13 and Figure 14). Neither Washington nor Oregon State have established criteria for specific conductance, nor have background turbidity levels for the established turbidity criteria been developed. All measurements met the MQO with the exception of the turbidity measurements taken in the Skipanon River during 2012, which did not meet the MQO for precision (Appendix A).

Table 13. Mean values of instantaneous water chemistry measurements taken in the Skipanon River, Colewort Creek and Megler Creek from 2012 to 2015.

Site	Year	Temperature (°C)	DO (mg/L)	Specific Conductivity (µS/cm)	pH*	Turbidity (NTU)
Skipanon River	2012	16.6	5.01	184.27	6.97	8.02
	2013	17.8	5.85	210.37	6.89	11.44
	2014	19.3	5.39	174.23	6.63	8.55
	2015	18.3	5.85	105.9	6.99	9.92
Colewort Creek	2012	12.7	9.20	87.87	7.37	0.66
	2013	13.1	9.45	101.69	6.82	0.72
	2014	15.4	8.70	100.56	6.97	0.99
	2015	14.7	8.47	99.2	6.84	1.08
Megler Creek	2012	12.8	9.82	88.69	7.13	1.63
	2013	12.2	10.68	105.39	7.14	1.55
	2014	13.3	10.25	105.93	7.30	1.18
	2015	13.2	10.02	106.1	7.60	0.57

*Median value is reported for pH.

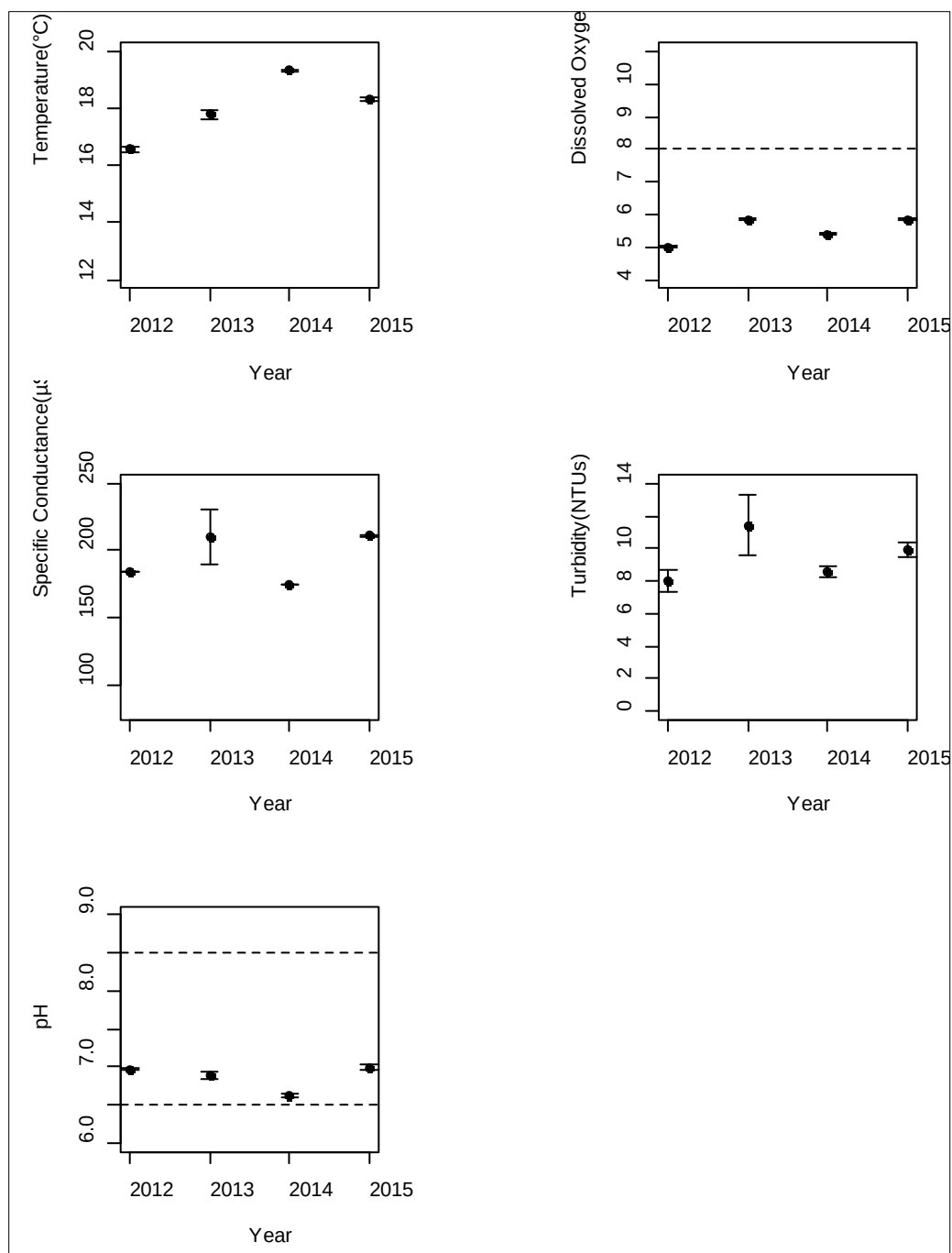


Figure 14. A plot of mean water chemistry measurements taken from the Skipanon River sample location from 2012 to 2015. All measures are reported as mean values, with the exception of pH, which are reported as the median. Upper and lower T-bars represent the standard deviation. Data points without error bars have standard deviations equal to zero. Dashed lines represent water quality criteria, established by CWA.

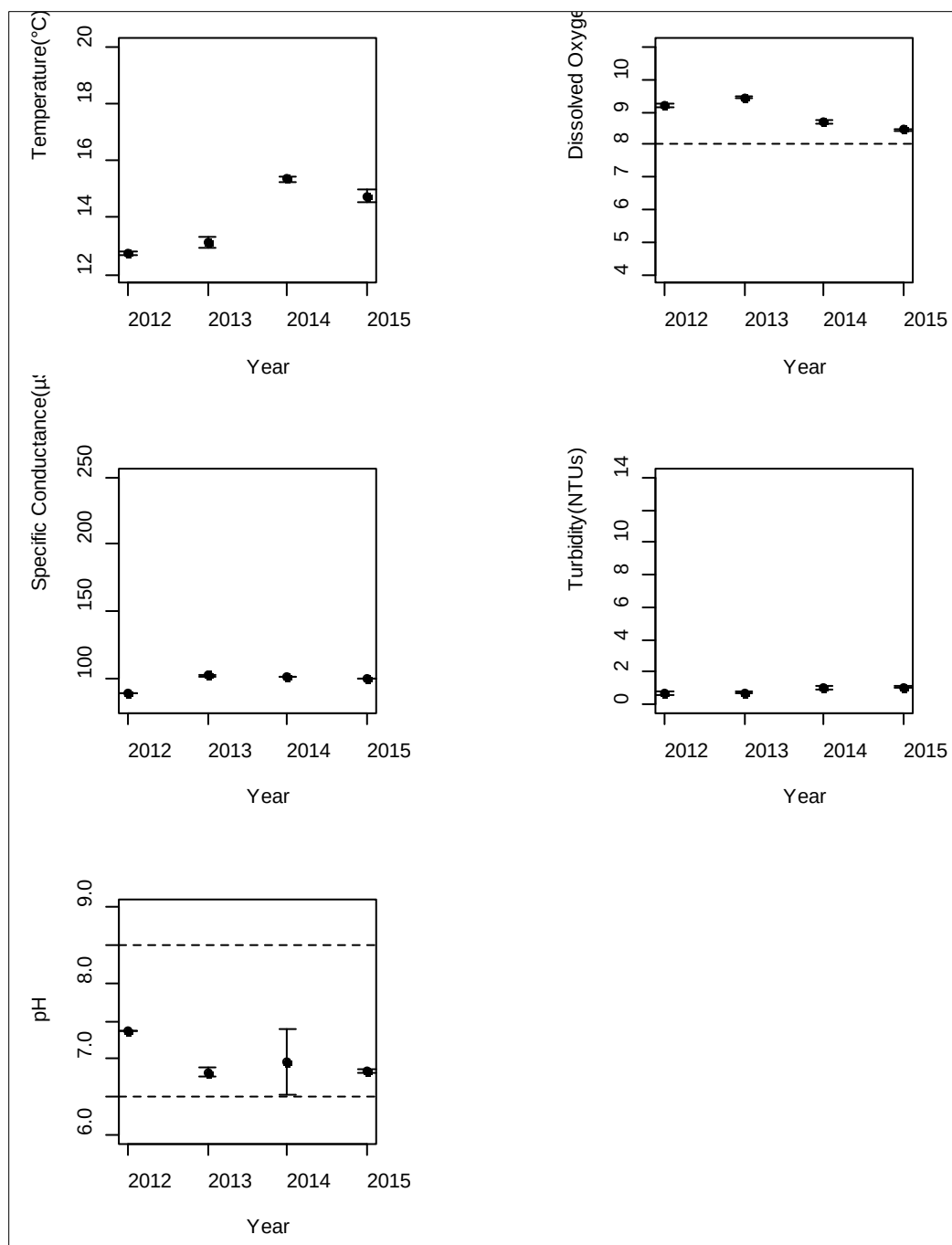


Figure 15. A plot of mean water chemistry measurements taken from the Colewort Creek sample location from 2012 to 2015. All measures are reported as mean values, with the exception of pH, which are reported as the median. Upper and lower T-bars represent the standard deviation. Data points without error bars have standard deviations equal to zero. Dashed lines represent water quality criteria, established by CWA.

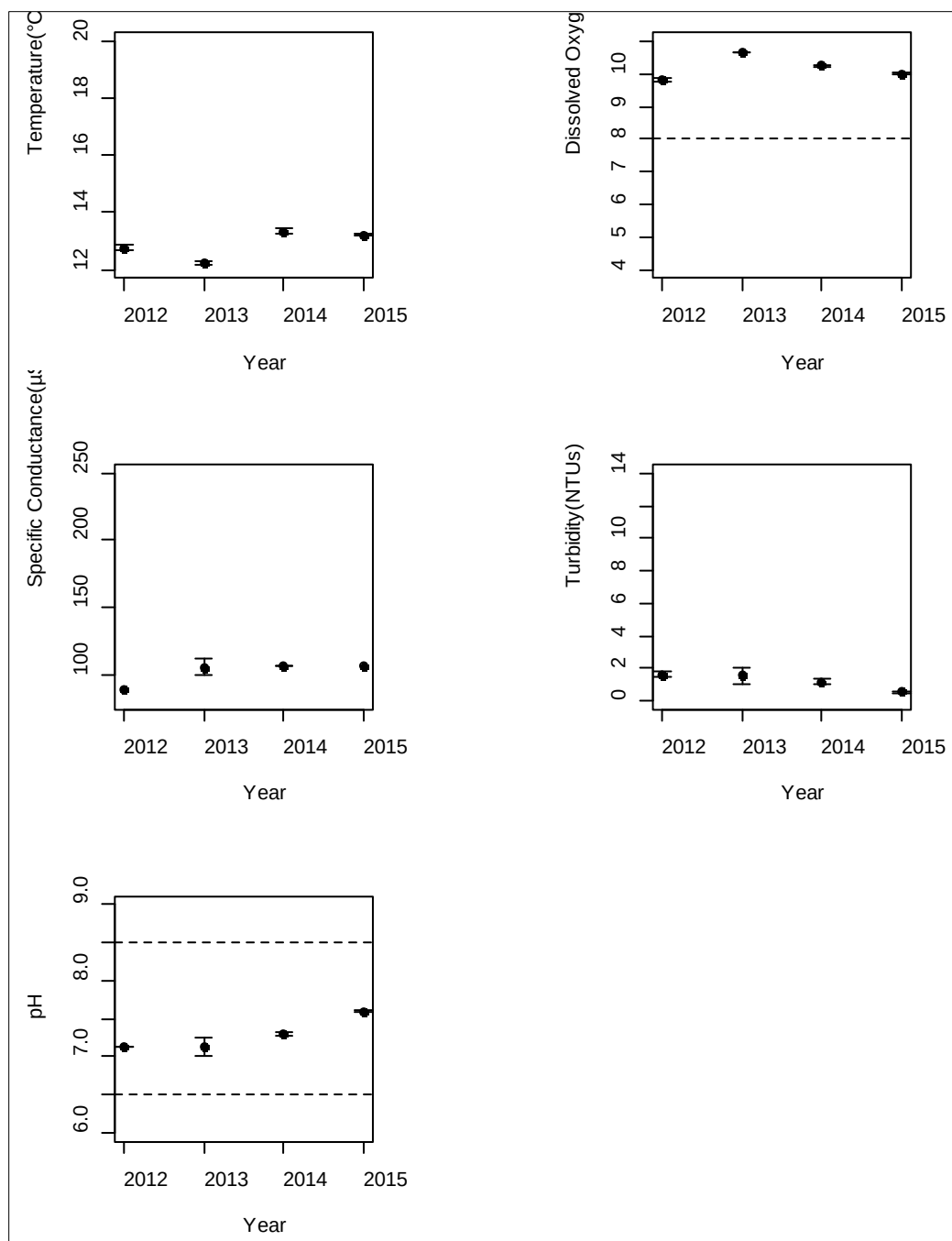


Figure 16. A plot of mean water chemistry measurements taken from the Megler Creek sample location from 2012 to 2015. All measures are reported as mean values, with the exception of pH, which are reported as the median. Upper and lower T-bars represent the standard deviation. Data points without error bars have standard deviations equal to zero. Dashed lines represent water quality criteria, established by CWA.

Continuous Temperature Data

Skipanon River

The water logger installed in the Skipanon River underwent several periods of dewatering in 2012 and 2015 due to tidal fluctuations (Table 14). In 2012, the water logger was serviced at low tide and was found exposed to air so it was moved to a deeper location in the river channel (Figure 17 and 18). Following this change, the water logger remained submerged through 2013 and 2014 leading to a continuous temperature record for this period. However, in 2015, the logger was disturbed by either people or high flows, and was again subjected to tidally influenced dewatering that created data gaps (Figure 19).

Despite these gaps it does appear that the summer water temperature increased over time (Figures 19 and 20) and the Skipanon River has failed to meet the CWA standards for temperature every year since monitoring was initiated. The 2013 and 2014 temperature record was complete and during that period the 13°C A7DMT criterion was exceeded for 55 and 58 days respectively. The 18°C A7DMT criterion was exceeded for 119 and 118 days respectively. Though incomplete, the temperature record for 2015 indicated that from October 15 to May 15 the 13°C A7DMT criterion was exceeded for 28 days, and the 18°C A7DMT criterion was exceeded for 56 days (Figure 21).

Table 14. Gaps in continuous water temperature measurements or when measurements were flagged and excluded from analysis.

Site	Water Year	Start Date	End Date	Notes	Flagged Data	
					# of Days	% for Year
Skipanon River	2012	10/1/2011	11/16/2011	Exposed to air	47	43
	2012	12/4/2011	12/26/2011	Exposed to air	22	43
	2012	1/10/2012	1/16/2012	Exposed to air	6	43
	2012	5/10/2012	7/31/2012	Exposed to air	82	43
	2015	1/13/2015	1/16/2015	Exposed to air	3	46
	2015	1/24/2015	2/4/2015	Exposed to air	12	46
	2015	2/15/2015	3/14/2015	Exposed to air	28	46
	2015	3/21/2015	3/23/2015	Exposed to air	3	46
	2015	3/30/2015	7/28/2015	Exposed to air	120	46
Colewort Creek	2012	10/1/2011	7/31/2012	Logger installed on 7/31/2012	304	84
Megler Creek	2011	10/1/2010	8/5/2011	Logger installed on 8/5/2011	308	86
	2015	1/13/2015	7/29/2015	Exposed to air	198	54



Figure 17. The water logger (blue circle) in the Skipanon River was dewatered during the 2012 site visit due to tidal fluctuation.



Figure 18. The Skipanon River water logger was deployed in the deepest portion of the river channel during the 2012 field visit. The photograph on the left depicts the water logger during low tide in 2014 and the photograph on the right shows the water logger in 2015 after it had been disturbed.

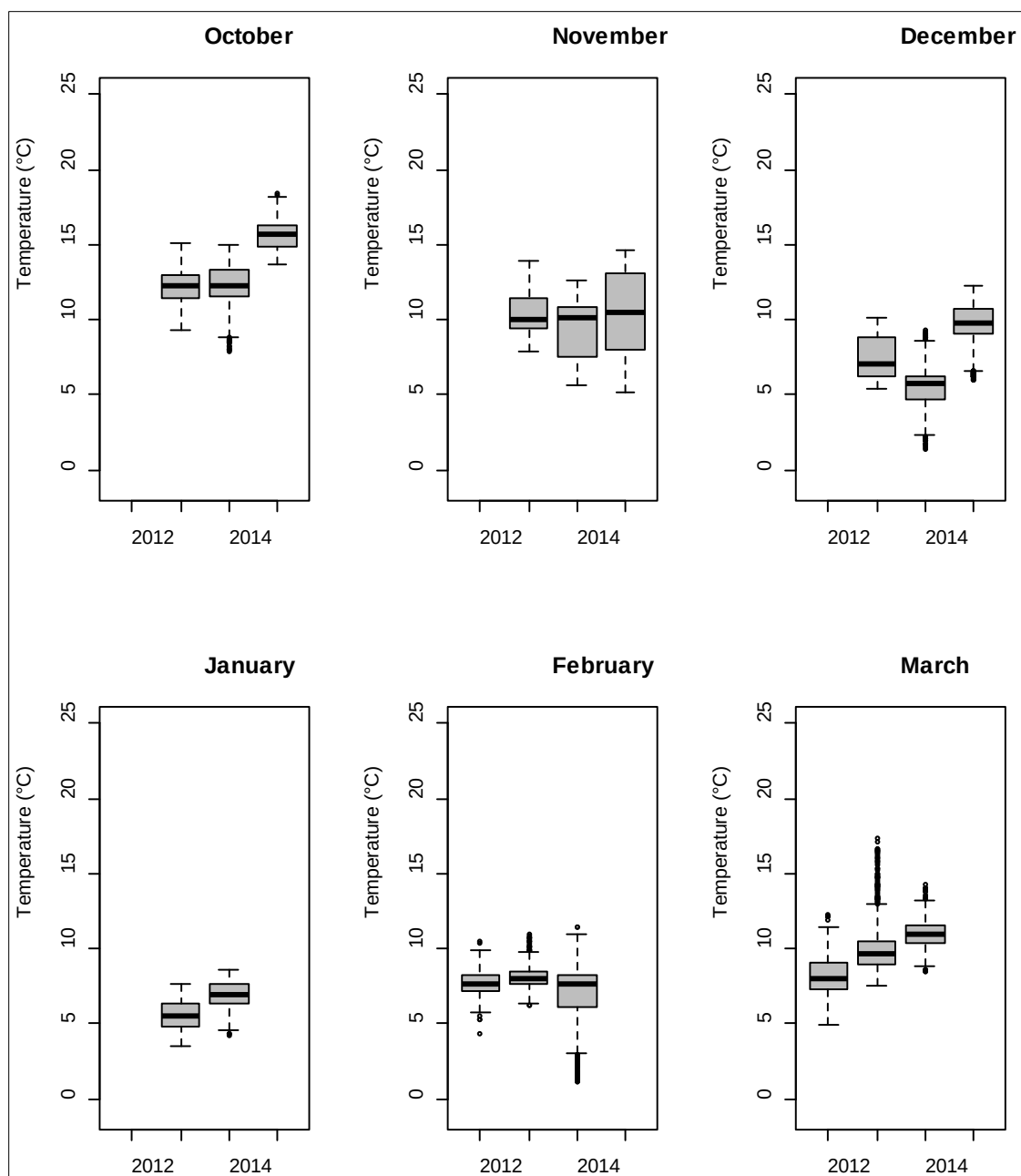


Figure 19. Box plots comparing the monthly distribution of hourly continuous water temperature measurements made in the Skipanon River for water years 2012 to 2015 (October through March). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper “Ts”. Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by circles.

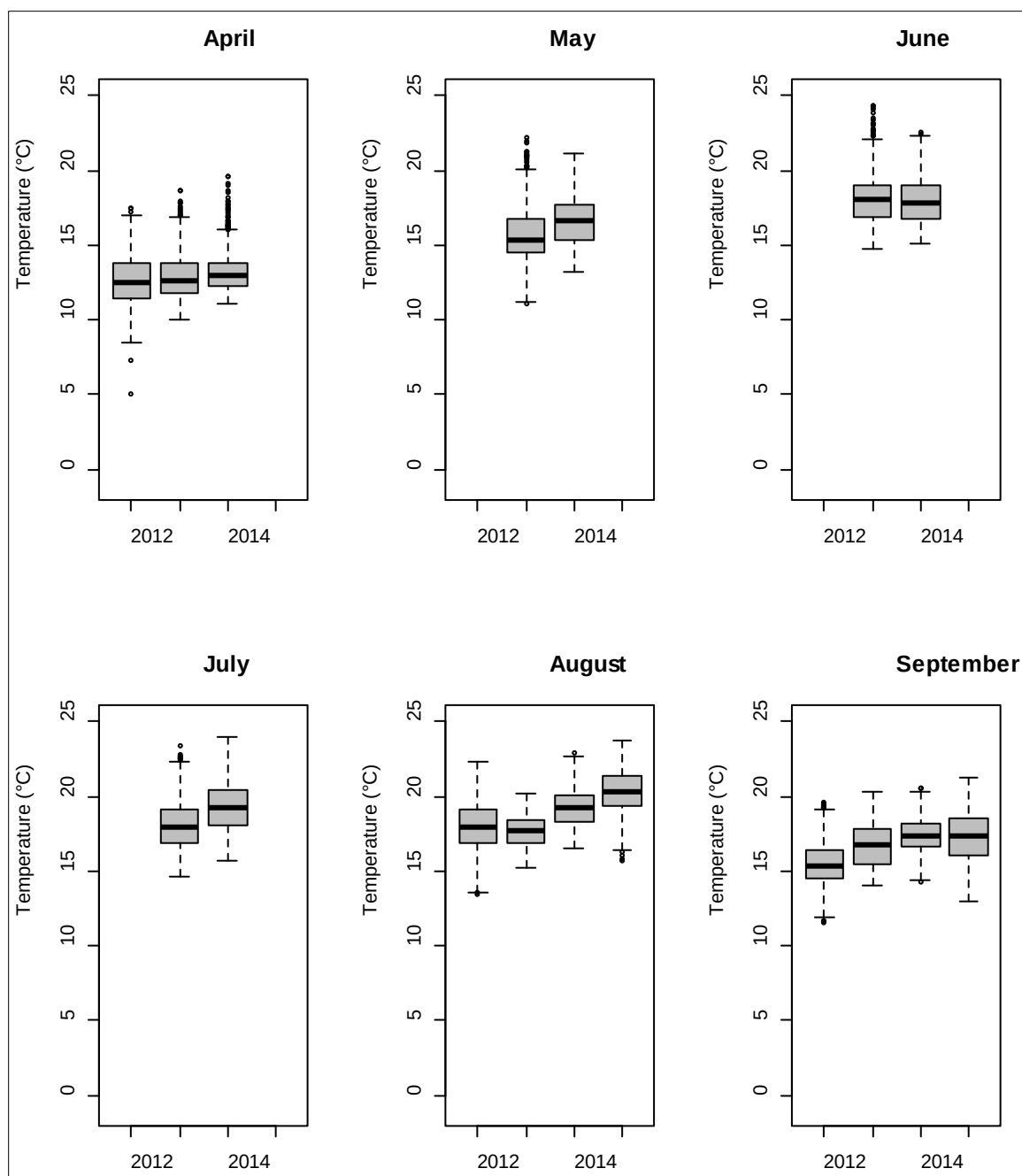


Figure 20. Box plots comparing the monthly distribution of hourly continuous water temperature measurements made in the Skipanon River for water years 2012 to 2015 (April through September). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper “Ts”. Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by circles.

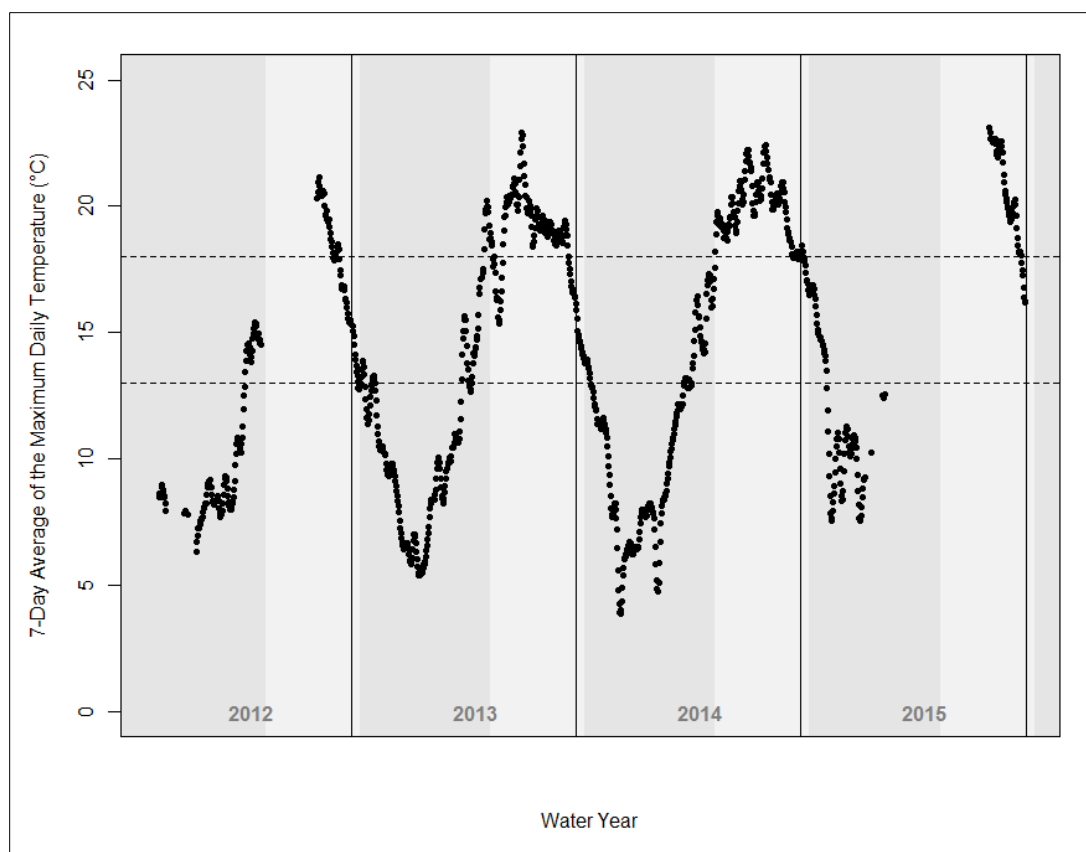


Figure 21. A plot of the daily A7DMT in the Skipanon River from 2012 to 2015. Dashed lines indicate the 18°C and 13°C criteria. Areas with the darker background have a 13°C maximum temperature criterion and areas with the lighter background have a designated 18°C maximum temperature criterion.

Colewort Creek

The Colewort Creek water logger has remained in place and unchanged since the station was installed in 2012, resulting in a continuous temperature data records with no gaps (Table 14 and Figure 22). Temperatures have increased modestly overtime during the winter and spring months, particularly for June; however, temperatures in the summer months did not indicate any trend in the data (Figures 23 and 24).

The A7DMT temperature did not exceed the aquatic designated beneficial uses for salmonid and trout rearing and migration criterion of 18 °C (Table 5 and Figure 24). However, the criterion for salmon and steelhead spawning of 13 °C was exceeded for three days in 2015 (Figure 25). Recent restoration efforts in Colewort Creek have resulted in adult salmon returning to the Creek. While not yet an established beneficial use for this stream, reevaluation of this site in future years will likely result in salmon/steelhead spawning use designation (Chris Clatterbuck, LEWI Chief of Resources, email communication, 04-20-2017).



Figure 22. The Colewort Creek water logger (blue circle), installed in 2012, has remained in place and unchanged since that time.

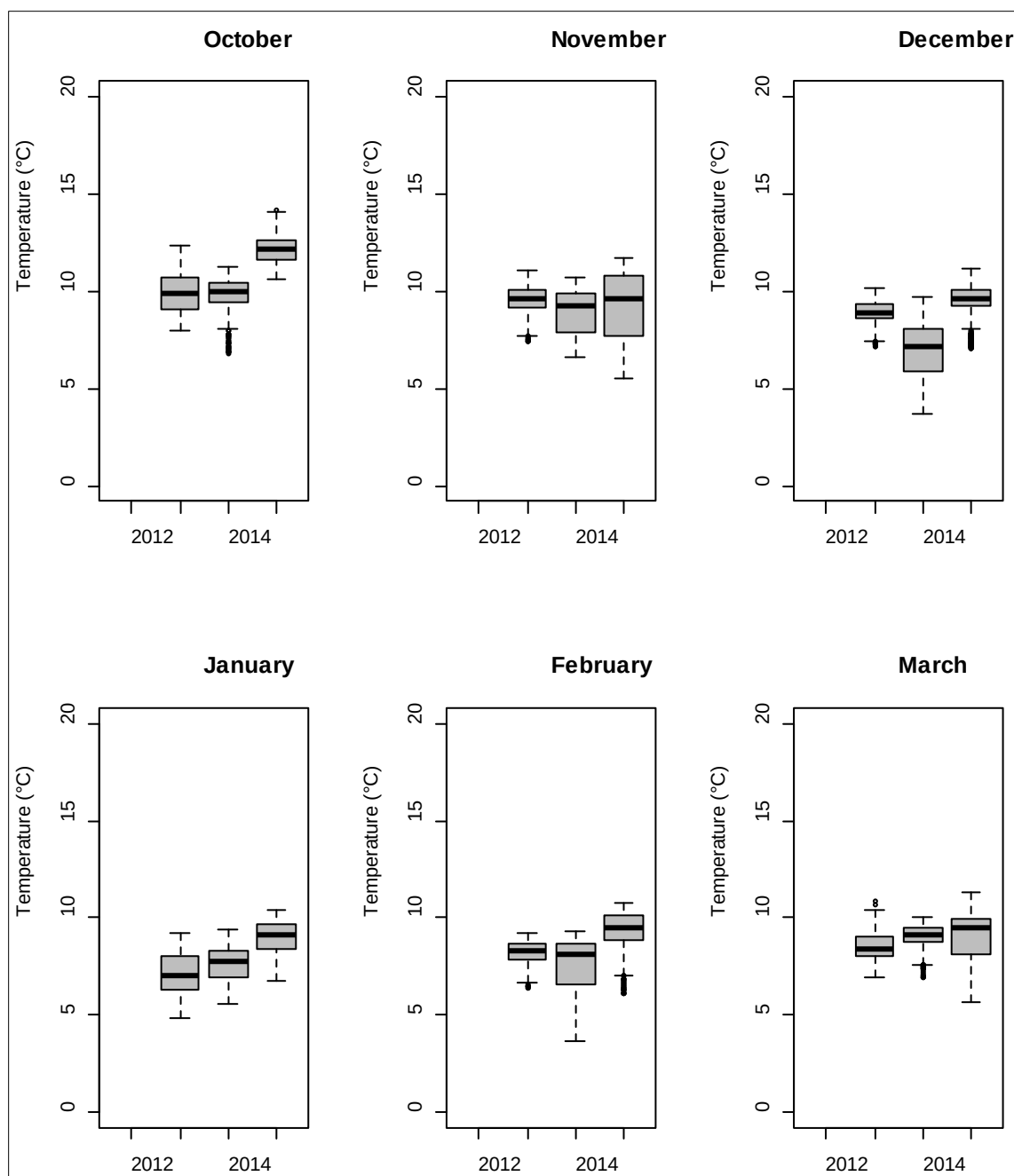


Figure 23. Box plots comparing the monthly distribution of hourly water temperatures in Colewort Creek for water years 2012 to 2015 (October through March). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper “Ts”. Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by circles.

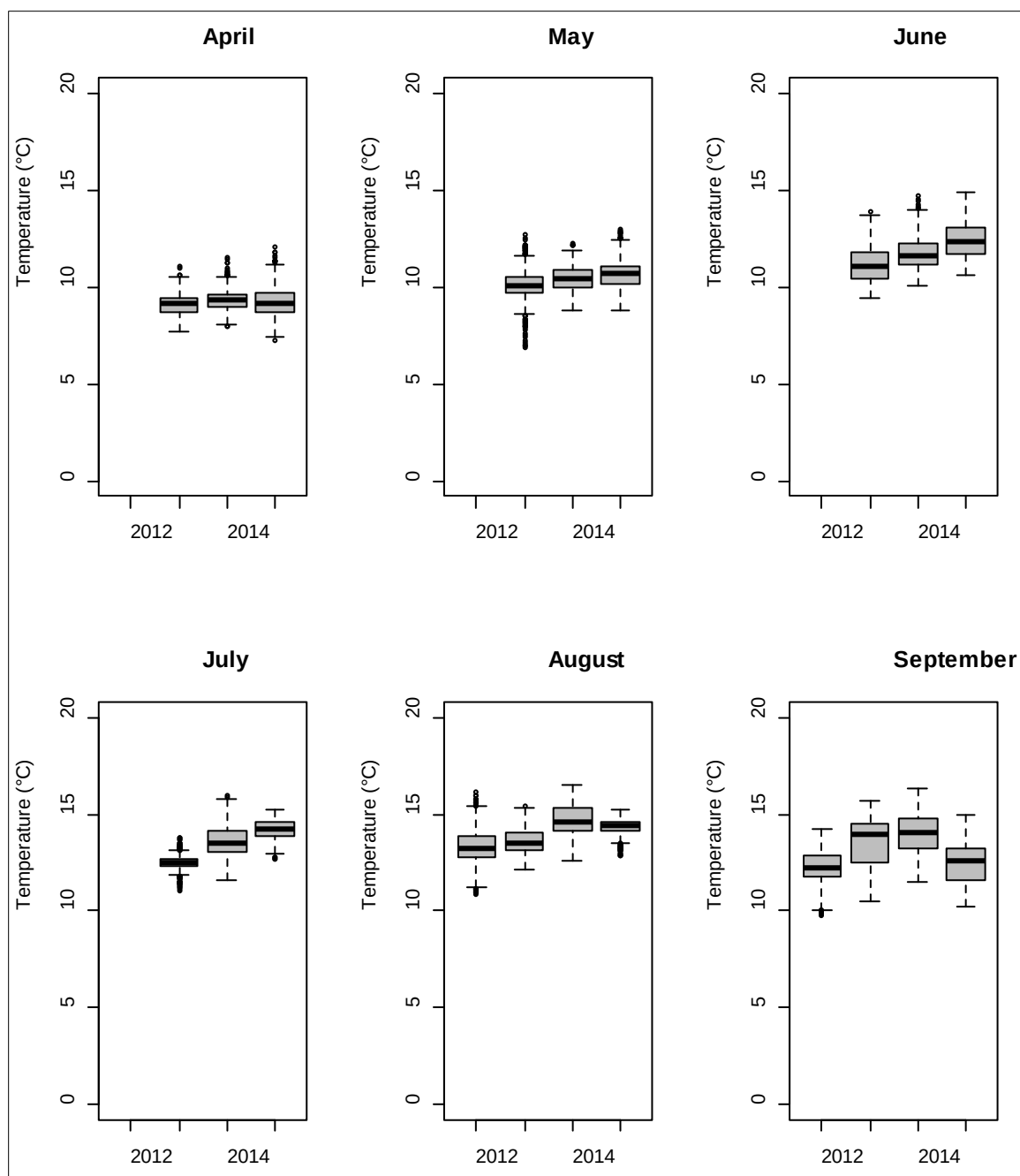


Figure 24. Box plots comparing the monthly distribution of hourly water temperatures in Colewort Creek for water years 2012 to 2015 (April through September). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper “Ts”. Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by circles.

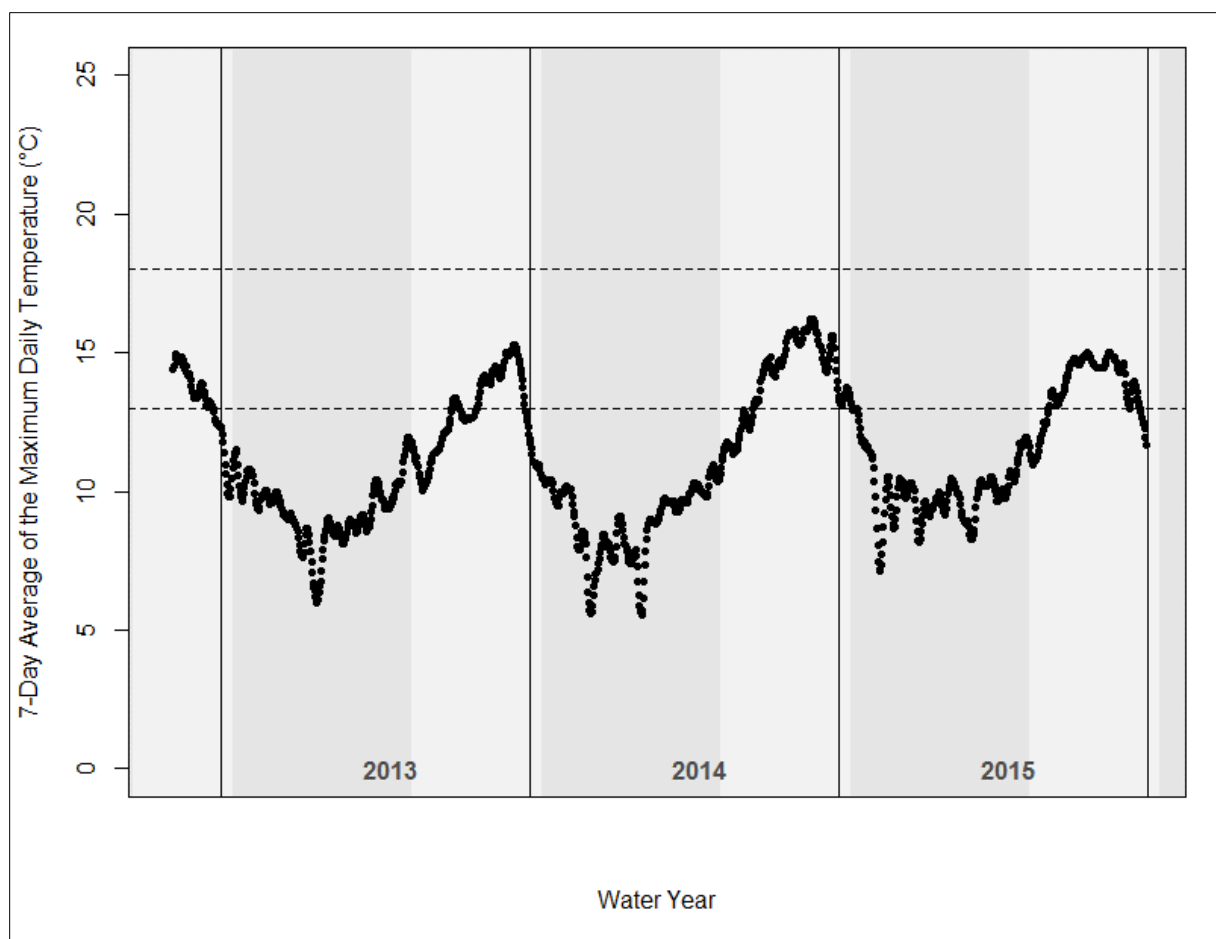


Figure. 25. A scatter plot of the daily A7DMT in Colewort Creek from July 31, 2012 to September 31, 2015. Dashed lines indicate 18°C and 13°C criteria. Areas with the darker background have a 13°C maximum temperature criterion and areas with the lighter background are times with an 18°C maximum temperature criterion. At this time, Colewort Creek only needs to meet the 18°C temperature criterion.

Megler Creek

The Megler Creek water logger was installed in August 2011 and to ensure a complete temperature record we had to adjust its location annually due to sediment deposition (Figure 26). However, in 2015 a large amount of sediment was deposited in the sample reach that shifted the channel and dewatered the water logger causing a loss of more than 50 percent of the data for the water year. With the data that was available, we did see a slight increase in monthly temperatures from year to year particularly in the fall and summer months (Figures 27 and 28). However, the A7DMT did not exceed the aquatic designated beneficial use criterion of 18 °C for the time period we were able to measure (Figure 29).



Figure 26. Photographs of the water logger installations in Megler Creek. The image on the left depicts the logger as installed in 2011, and the image on the right depicts the logger partially buried in sediment as found during the 2012 site visit.

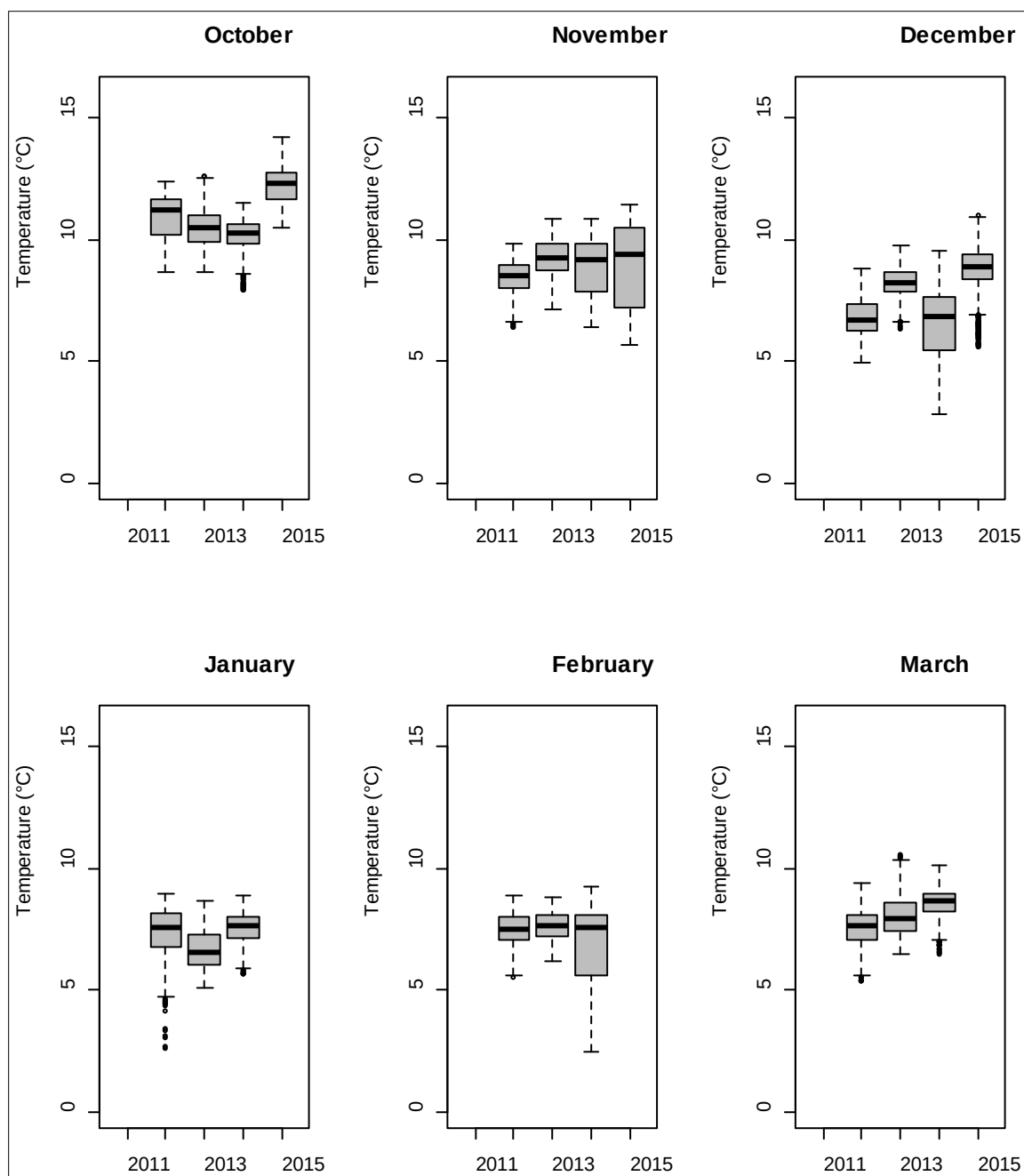


Figure 27. Box plots comparing the monthly distribution of hourly continuous water temperature measurements made in Megler Creek for water years 2011 to 2015 (October through March). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper “Ts”. Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by circles.

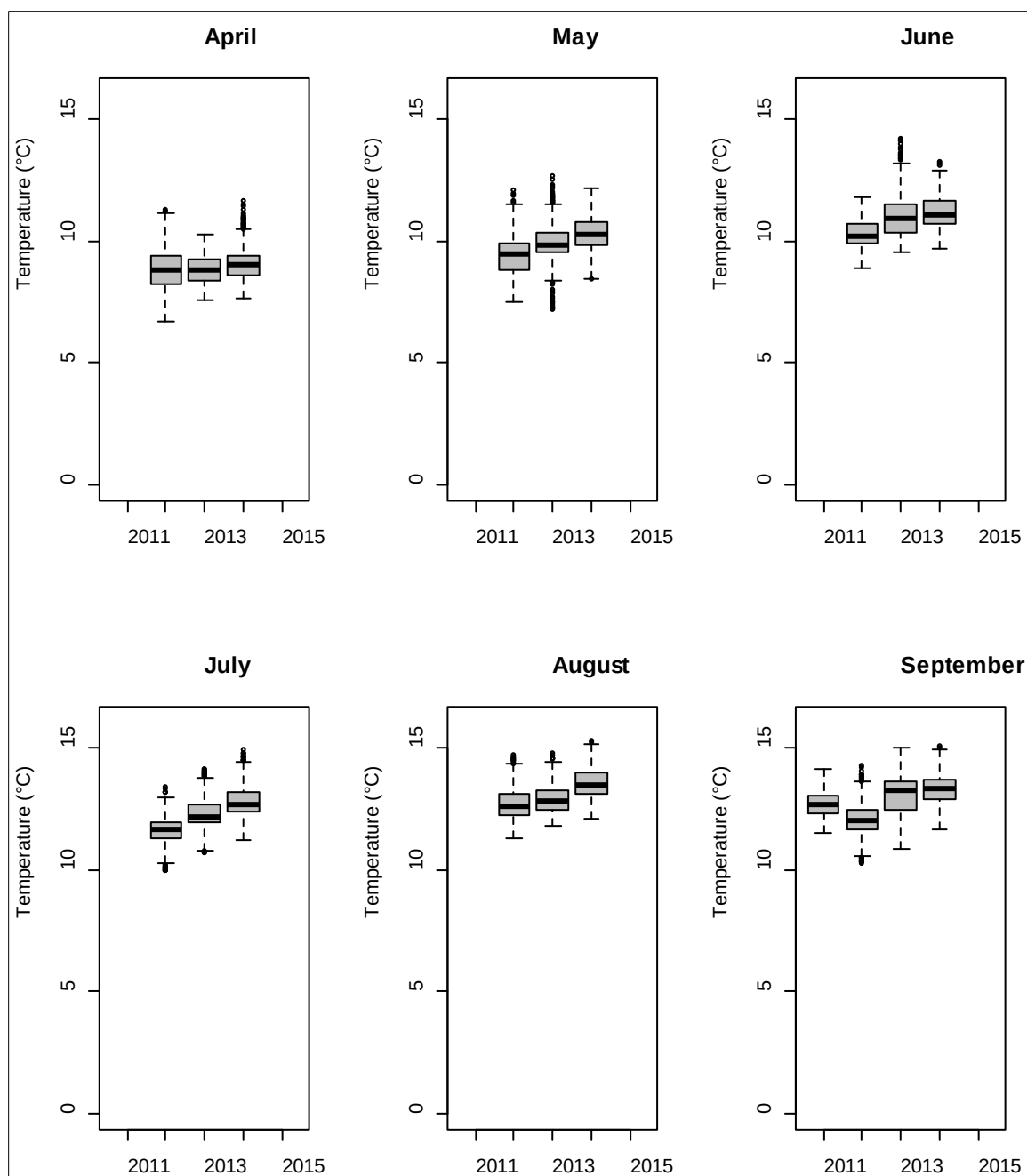


Figure 28. Box plots comparing the monthly distribution of hourly continuous water temperature measurements made in Megler Creek for water years 2011 to 2015 (April through September). Months missing more than 10% of the temperature record were not plotted. The gray boxes represent the upper and lower quartiles of the data (upper and lower edges of the box), and the median is represented by the thick horizontal black line. The range of the data, excluding outliers, is denoted by the lower and upper “Ts”. Outliers are data 1.5 times higher or lower than the 75th and 25th percentiles, and are represented by circles.

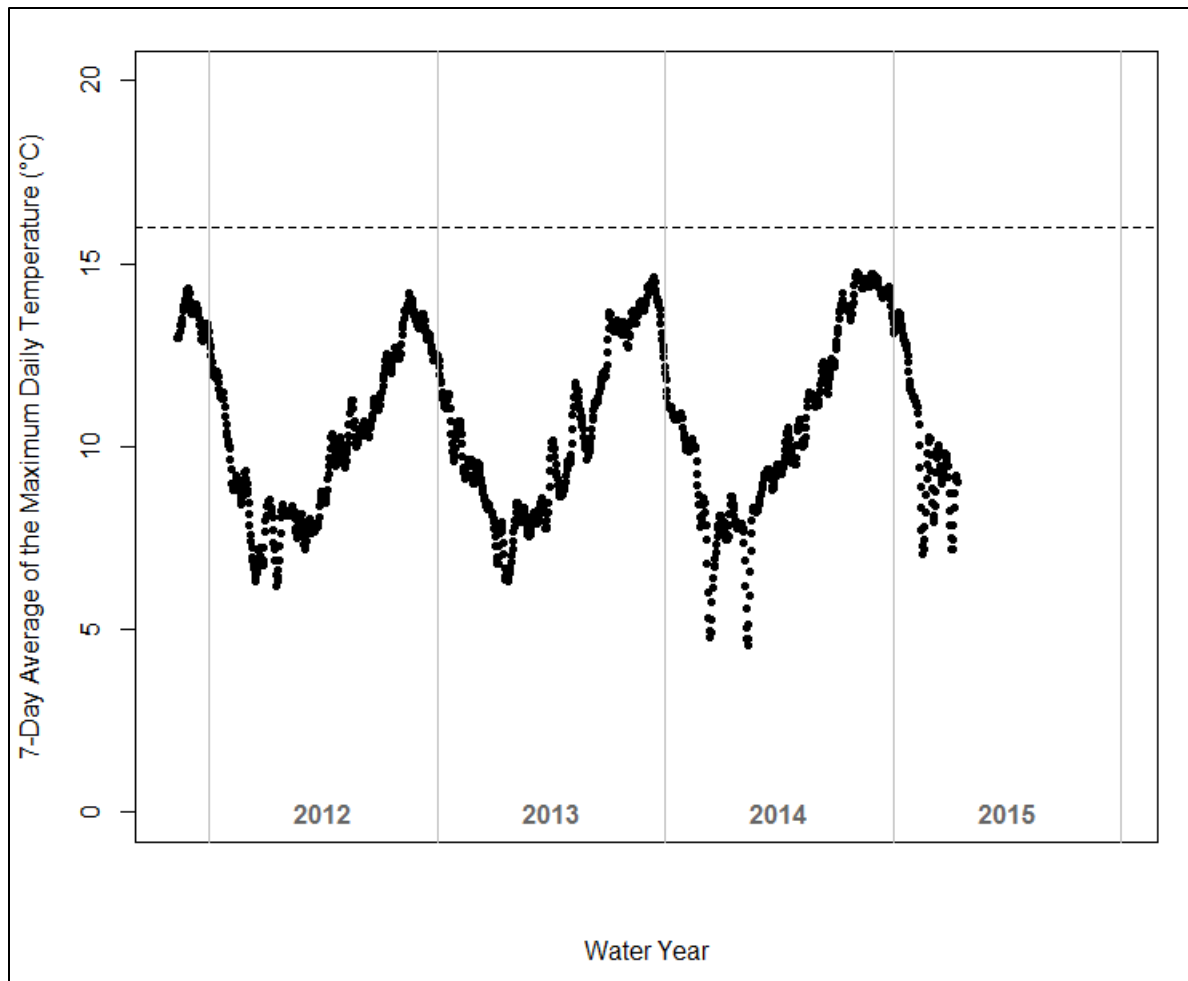


Figure 29. The A7DMT in Megler Creek for water years 2012 to 2015. Water temperature did not exceeded the 16 °C criterion during this period of time, as indicated by the dashed line.

Stream Habitat

Measures of precision were not calculated for wetted width, bankfull width and thalweg depth, from 2012 to 2015, for any of the three sample locations in LEWI. These measures will be included in future assessments. Accuracy and bias were calculated for wetted and bankfull widths, at all three sample locations in LEWI, and both parameters have passed MQO from 2012 to 2015, (Tables 3 and 4; and Appendix A).

Skipanon River

Measurements of wetted width, bankfull width and thalweg depth, in 2015, were within the range of 2012, 2013 and 2014 surveys, however, the maximum wetted width and thalweg depth were 20% wider and 30% deeper in 2015 (Table 15). The Rapid Habitat Assessment, in 2015, classified the habitat conditions in the sample reach as marginal which was an improvement from the 2014 survey which classified the habitat conditions as poor (Table 15).

Colewort Creek

Measurements of wetted width, bankfull width and thalweg depth, in 2015, were within the range of 2012, 2013 and 2014 surveys, however, the maximum thalweg depth, in 2015, was 30% deeper than the previous maximum for this parameter (Table 15). The Rapid Habitat Assessment, in 2015, classified the habitat conditions in the sample reach as sub-optimal, which reflects the results from previous years surveys (Table 15).

Megler Creek

Measurements of wetted width, bankfull width and thalweg depth, in 2015, were within the range of 2012, 2013 and 2014 surveys (Table 15). The Rapid Habitat Assessment, in 2015, classified the habitat conditions in the sample reach as optimal, which reflects the results from the 2014 survey (Table 15).

Table 15. LEWI Rapid Habitat Assessment and physical habitat measurements, 2012 to 2015.

Site	Year	Rapid Habitat Score*	Wetted Width (m)			Bankfull Width (m)			Thalweg Depth (m)		
			Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Skipanon	2012	92	4.6	5.9	5.1	5.6	8.2	6.5	0.53	0.79	0.63
	2013	79	4.3	5.2	4.7	5.9	9.8	7.2	0.50	0.75	0.63
	2014	48	2.8	5.1	4.5	6.5	7.9	7.1	0.43	0.75	0.55
	2015	83	4.6	7.3	5.4	5.0	6.1	5.7	0.47	1.12	0.71
Colewort	2012	125	0.8	2.2	1.6	1.9	3.0	2.3	0.05	0.20	0.10
	2013	131	0.8	2.4	1.4	2.0	3.8	2.7	0.02	0.42	0.13
	2014	150	0.8	3.6	1.6	2.8	4.6	3.5	0.04	0.34	0.15
	2015	146	0.8	2.8	1.8	2.0	4.7	3.2	0.10	0.59	0.26
Megler	2012	145	0.8	4.2	2.2	4.4	6.2	5.0	0.04	0.25	0.20
	2013	119	1.0	3.6	2.3	4.3	6.7	5.2	0.02	0.15	0.06
	2014	170	1.3	2.8	1.9	3.1	5.6	4.1	0.06	0.18	0.10
	2015	159	1.1	2.3	1.4	4.4	5.2	4.4	0.05	0.20	0.09

*Rapid habitat measure is a sum of values, out of 200 possible.

Invasive Plants and Animals

Skipanon River

Since monitoring was initiated, Skipanon River sample reach has been colonized by five species of invasive plants and one animal species (Table 16).

Table 16. Invasive species observations in the Skipanon River from 2012 to 2015. TNTC=Too numerous to count.

Year	Invasive Species	Estimated Abundance (stems)	Estimated Area of Influence (m²)
2012	Reed canary grass (<i>Phalaris arundinacea</i>)	TNTC	>100
	Evergreen blackberry (<i>Rubus laciniatus</i>)	Present	<1
	Birdsfoot trefoil (<i>Lotus corniculatus</i>)	Present	<1
	Himalayan blackberry (<i>Rubus bifrons</i>)	>50	2
	New Zealand Mud snail (<i>Potamopyrgus antipodarum</i>)	>1861	NA
2013	Reed canary grass (<i>Phalaris arundinacea</i>)	TNTC	>100
	Evergreen blackberry (<i>Rubus laciniatus</i>)	>10	5
	Birdsfoot trefoil (<i>Lotus corniculatus</i>)	>100	25
	Purple loosestrife (<i>Lythrum salicaria</i>)	2	<1
	New Zealand Mud snail (<i>Potamopyrgus antipodarum</i>)	>948	NA
2014	Reed canary grass (<i>Phalaris arundinacea</i>)	TNTC	>100
	Evergreen blackberry (<i>Rubus laciniatus</i>)	TNTC	20
	Birdsfoot trefoil (<i>Lotus corniculatus</i>)	>50	5
	Purple loosestrife (<i>Lythrum salicaria</i>)	>10	<1
	Brazilian elodea (<i>Egeria densa</i>)	3	<1
	New Zealand Mud snail (<i>Potamopyrgus antipodarum</i>)	>2247	NA
2015	Reed canary grass (<i>Phalaris arundinacea</i>)	TNTC	>100
	Evergreen blackberry (<i>Rubus laciniatus</i>)	TNTC	20
	Birdsfoot trefoil (<i>Lotus corniculatus</i>)	>50	5
	Purple loosestrife (<i>Lythrum salicaria</i>)	Present	<1
	Brazilian elodea (<i>Egeria densa</i>)	Present	<1
	New Zealand Mud snail (<i>Potamopyrgus antipodarum</i>)	>1716	NA

Colewort Creek

The Colewort Creek sample reach is largely dominated by native vegetation; however, small patches of four non-native plant species have been documented since monitoring was initiated (Table 17).

Table 17. Invasive species observations in Colewort Creek, 2012 to 2015. NA = Not applicable.

Year	Invasive Species	Estimated Abundance (stems)	Estimated Area of Influence (m ²)
2013	Reed canary grass (<i>Phalaris arundinacea</i>)	>1,000	2
	Evergreen blackberry (<i>Rubus laciniatus</i>)	2	1
2015	Himalayan blackberry (<i>Rubus bifrons</i>)	3	2 m ²
	Creeping buttercup (<i>Ranunculus repens</i>)	>10	1 m ²

Megler Creek

The Megler Creek sample reach is largely dominated by native vegetation however, small patches of three non-native plant species have been documented since monitoring was initiated (Table 18).

Table 18. Invasive species observations in Megler Creek, 2012 to 2015. NA = Not applicable.

Year	Invasive species	Estimated Abundance (stems)	Estimated Area of Influence (m ²)
2013	New Zealand Mud snail (<i>Potamopyrgus antipodarum</i>)	1	NA
2014	Sheep sorel (<i>Rumex acetosella</i>)	2	<1
	Fox glove (<i>Digitalis sp.</i>)	2	<1
2015	Creeping buttercup (<i>Ranunculus repens</i>)	>1000	Undetermined

Benthic Macroinvertebrates

Skipanon River

Eleven taxa were collected from the Skipanon River in 2015, which were primarily represented by mollusks and amphipods (Table 19). Both richness and the number of taxa that are expected to occur in a sample under reference conditions have decreased over time indicating a decrease in the ecological conditions of the sample reach (Table 19). The results for the remaining index values showed little change and should be interpreted with caution since a large percentage of the organisms in the samples did not have established tolerance values.

Table 19. Metric values for the biological condition of the Skipanon River, Colewort Creek, and Megeler Creek for samples collected from 2012 to 2015. Numbers in parentheses indicate the percent of the organisms in the sample that did not have assigned tolerance values.

Site	Year	Richness (R)	Diversity (D)	Taxonomic Completeness (O/E)	Temperature Index (TI)	Fine Sediment Index (FSI)	Metal Tolerance Index (MTI)	Nutrient Index (NI)
Skipanon	2012	17	0.77	0.19	15(91)	37(91)	2.9(92)	7.0(91)
	2013	14	0.69	0.12	14(95)	26(95)	2.5(94)	5.4(94)
	2014	15	0.68	0.12	15(87)	40(87)	3.1(88)	7.6(87)
	2015	11	0.62	0.13	15(96)	38(96)	3.1(96)	7.4(97)
Colewort	2012	30	0.88	0.78	13(20)	22(20)	3.2(43)	4.7(27)
	2013	35	0.91	0.77	13(25)	23(25)	1.9(40)	5.2(44)
	2014	27	0.88	0.52	13(54)	24(54)	2.2(59)	5.5(68)
	2015	31	0.86	0.77	12(38)	21(38)	2.2(50)	3.6(62)
Megler	2012	33	0.78	0.84	14(3)	24(3)	4.2(17)	5.5(17)
	2013	45	0.94	0.97	13(9)	22(9)	2.4(27)	4.1(38)
	2014	47	0.94	0.97	13(16)	22(16)	2.4(30)	4.6(48)
	2015	44	0.92	0.97	13(4)	21(4)	2.0(24)	5.4(39)

Colewort Creek

Thirty-one taxa were collected from the Colewort Creek in 2015, which were primarily represented by non-insect taxa, Diptera taxa (flies), and Plecoptera taxa (stoneflies) (Table 19). Richness, defined as the number of taxa collected, and the number of taxa that are expected to occur in a sample under reference conditions have remained relatively constant over time; the results for the remaining index values also showed little change (Table 19).

Megler Creek

Forty-four taxa were collected from the Megler Creek in 2015, which were primarily represented by Ephemeroptera (mayflies), and Plecoptera taxa (Table 19). Richness and the number of taxa that are expected to occur in a sample under reference conditions have increased over time indicating an improvement in the ecological conditions of the sample reach. However, the remaining index values have showed little change (Table 19).

Incidental Observations

Since the initiation of monitoring, several taxa of interest have been documented in the three LEWI sample reaches. In the Skipanon River, in 2012 and 2013, field crews found an unidentified sculpin species (Figure 30). In 2012, a native crayfish in the genus *Pacifastacus* was collected and a juvenile river otter (*Lontra canadensis*) was observed. In Colewort Creek, in 2014, seven Northern red-legged frogs (*Rana aurora*) were counted (Figure 31). In 2015, two unidentified sculpin, a Northern red-legged frog, a western chorus frog (*Psuedacris triseriata*), and a northwest salamander (*Ambystoma gracile*) was observed. An unidentified crayfish was observed but not caught, in the Megler Creek sample reach, in 2012.



Figure 30. Unidentified sculpin from the Skipanon River, 2013.



Figure 31. Northern red-legged from Colewort Creek, 2015.

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Appendix A. Measurement quality objectives.

Table A-1. Precision (RPD) measurement quality objective results from Ebey's Watercourse, 2013 through 2015 (DO = dissolved oxygen. ND = Not Determined).

Site	Year	Instantaneous Measurements					Continuous Temperature				Habitat Measurements		
		Temperature	D.O.	Specific Conductivity	pH	Turbidity	Water Pre-deployment	Water Post-deployment	Air Pre-deployment	Air Post-deployment	Wetted Width	Bankful Width	Thalweg Depth
Ebey's Water-course	2013	<0.01	<0.01	0.30	0.15	0.87	<0.01	0.1	<0.01	<0.01	ND	ND	ND
	2014	<0.01	0.03	0.02	0.36	7.83	<0.01	<0.01	<0.01	<0.01	ND	ND	ND
	2015	<0.01	<0.01	0.30	0.15	0.87	<0.01	0.05	<0.01	<0.01	ND	ND	ND

Table A-2. Accuracy and Bias (PD) measurement quality objective results from Ebey's Watercourse, 2013 through 2015 (Pre = Pre-deployment. Post = Post-deployment. DO = dissolved oxygen. ND = Not determined).

Site	Year	Instantaneous Temperature		D.O.		Specific Conductivity		pH		Turbidity		Continuous Water		Continuous Air		Wetted Width	Bankful Width
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post		
Ebey's Water-course	2013	0.08	<0.01	ND	ND	0.70	1.57	<0.01	0.99	ND	ND	0.05	0.04	0.01	0.02	<0.01	<0.01
	2014	0.20	0.19	ND	ND	7.46	0.10	0.14	0.28	ND	ND	0.06	0.02	0.06	0.03	<0.01	<0.01
	2015	0.08	0.07	ND	ND	5.93	0.35	0.14	0.25	ND	ND	0.06	0.02	0.06	0.03	<0.01	<0.01

Table A-3. Sensitivity (AMS) measurement quality objective results from Ebey's Watercourse, 2013 through 2015. (DO = dissolved oxygen).

Site	Year	Instantaneous Measurements					Continuous Temperature			
		Temperature	D.O.	Specific Conductivity	pH	Turbidity	Water Pre-deployment	Water Post-deployment	Air Pre-deployment	Air Post-deployment
Ebey's Water-course	2013	<0.01	0.03	26.97	0.06	0.70	<0.01	0.10	<0.01	0.10
	2014	<0.01	0.02	1.98	0.15	1.43	0.15	<0.01	<0.01	<0.01
	2015	0.14	0.07	2.92	0.04	2.07	0.05	0.04	0.04	0.04

Table A-4. Precision (RPD) measurement quality objective results from all three LEWI sample locations, 2012 through 2015. (DO = dissolved oxygen. NA = not applicable. ND = Not determined).

Site	Year	Instantaneous Measurements					Continuous Temperature				Habitat Measurements		
		Temperature	D.O.	Specific Conductivity	pH	Turbidity	Water Pre-deployment	Water Post-deployment	Air Pre-deployment	Air Post-deployment	Wetted Width	Bankful Width	Thalweg Depth
Skipanon River	2011	<0.01	50	1.88	50	NA	<0.01	<0.01	0.03	<0.01	ND	ND	ND
	2012	0.2	<0.01	0.04	0.04	4.80	<0.01	<0.01	0.03	<0.01	ND	ND	ND
	2013	0.3	0.17	5.81	0.29	10.21	<0.01	<0.01	<0.01	0.16	ND	ND	ND
	2014	0.1	0.46	0.09	0.30	3.10	<0.01	<0.01	<0.01	0.16	ND	ND	ND
	2015	<0.01	0.08	0.05	0.07	1.11	<0.01	ND	<0.01	0.16	ND	ND	ND
Colewort Creek	2012	0.2	0.38	0.06	<0.01	0.38	<0.01	ND	<0.01	0.10	ND	ND	ND
	2013	0.8	0.29	0.25	0.47	0.69	<0.01	ND	<0.01	0.10	ND	ND	ND
	2014	0.3	0.11	0.03	4.92	7.21	<0.01	ND	<0.01	0.10	ND	ND	ND
	2015	1.0	0.15	0.18	0.22	1.83	<0.01	ND	<0.01	0.10	ND	ND	ND
Megler Creek	2011	50	50	0.16	50	ND	<0.01	<0.01	<0.01	<0.01	ND	ND	ND
	2012	0.6	0.25	0.03	<0.01	1.94	<0.01	<0.01	<0.01	<0.01	ND	ND	ND
	2013	<0.01	0.05	2.37	1.24	0.84	<0.01	0.10	0.02	0.14	ND	ND	ND
	2014	0.4	0.12	0.05	0.31	0.84	<0.01	0.10	0.02	0.14	ND	ND	ND
	2015	0.19	0.12	0.02	<0.01	<0.01	<0.01	0.10	0.02	0.14	ND	ND	ND

Table A-5. Accuracy and Bias (PD) measurement quality objective results from all three LEWI sample locations, 2012 through 2015. (Pre = Pre-deployment. Post = Post-deployment. DO = dissolved oxygen. NA = not applicable. ND = Not determined).

Site	Year	Instantaneous Temperature		D.O.		Specific Conductivity		pH		Turbidity		Continuous Water		Continuous Air		Wetted Width	Bankful Width
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post		
Skipanon River	2011	<0.01	0.2	ND	ND	NA	NA	NA	NA	ND	ND	0.09	0.04	0.03	0.04	<0.01	<0.01
	2012	0.2	0.2	ND	ND	2.04	1.28	1.55	0.43	ND	ND	0.09	0.04	0.03	0.04	<0.01	<0.01
	2013	0.1	<0.01	ND	ND	5.66	7.58	0.57	1.45	ND	ND	0.07	0.11	0.01	0.14	<0.01	<0.01
	2014	0.1	0.1	ND	ND	0.64	0.57	0.14	1.27	ND	ND	0.07	0.11	0.01	0.14	<0.01	<0.01
	2015	0.1	0.1	ND	ND	<0.01	0.50	0.14	0.29	ND	0.81	0.15	ND	0.01	0.14	<0.01	<0.01
Colewort Creek	2012	0.2	0.2	ND	ND	2.04	1.28	1.55	0.43	ND	ND	0.15	0.10	0.07	ND	<0.01	<0.01
	2013	0.1	<0.01	ND	ND	5.66	7.58	0.57	1.45	ND	ND	0.15	0.10	0.07	ND	<0.01	<0.01

Table A-5 (continued). Accuracy and Bias (PD) measurement quality objective results from all three LEWI sample locations, 2012 through 2015. (Pre = Pre-deployment. Post = Post-deployment. DO = dissolved oxygen. NA = not applicable. ND = Not determined).

Site	Year	Instantaneous Temperature		D.O.		Specific Conductivity		pH		Turbidity		Continuous Water		Continuous Air		Wetted Width	Bankful Width
Colewort Creek (continued)	2014	0.1	0.1	ND	ND	0.20	0.81	0.14	1.27	ND	ND	0.15	0.10	0.07	ND	<0.01	<0.01
	2015	0.2	0.2	ND	ND	0.2	0.81	0.14	0.29	0.81	0.15	0.15	0.10	0.07	ND	<0.01	<0.01
Megler Creek	2011	<0.01	0.2	ND	ND	ND	ND	ND	ND	ND	ND	0.04	0.07	0.05	0.02	<0.01	<0.01
	2012	0.2	<0.01	ND	ND	6.54	2.04	0.14	0.43	ND	ND	0.04	0.07	0.05	0.02	<0.01	<0.01
	2013	0.1	<0.01	ND	ND	0.7	1.19	0.57	0.99	ND	ND	0.08	0.11	0.12	0.14	<0.01	<0.01
	2014	0.19	0.18	ND	ND	0.63	0.56	0.28	1.27	ND	ND	0.08	0.11	0.12	0.14	<0.01	<0.01
	2015	0.10	0.09	ND	ND	0.20	0.81	0.14	0.29	ND	0.81	0.08	0.11	0.12	0.14	<0.01	<0.01

Table A-6. Sensitivity (AMS) measurement quality objective results from all three LEWI sample locations, 2012 through 2015. (DO = dissolved oxygen. NA = not applicable. ND = Not determined).

Site	Year	Instantaneous Measurements					Continuous Temperature			
		Temperature	D.O.	Specific Conductivity	pH	Turbidity	Water Pre-deployment	Water Post-deployment	Air Pre-deployment	Air Post-deployment
Skipanon River	2011	NA	NA	NA	NA	NA	<0.01	0.04	0.05	<0.01
	2012	0.3	0.1	0.41	0.04	2.46	<0.01	0.04	0.05	<0.01
	2013	0.5	0.1	74.63	0.18	6.79	<0.01	0.01	0.05	0.55
	2014	0.2	0.1	1.26	0.11	1.28	<0.01	0.04	0.05	0.55
	2015	0.2	0.05	0.69	0.04	0.74	0.07	ND	0.05	0.55
Colewort Creek	2012	0.2	0.19	0.28	0.02	0.37	0.04	0.25	0.04	ND
	2013	0.6	0.14	2.73	0.21	0.16	0.04	0.25	0.04	ND
	2014	0.4	0.17	1.43	1.63	0.47	0.04	0.25	0.04	ND
	2015	0.9	0.12	1.06	0.08	0.16	0.04	0.25	0.04	ND
Megler Creek	2011	NA	NA	NA	NA	NA	0.05	<0.01	<0.01	<0.01
	2012	0.5	0.13	0.14	0.03	0.69	0.05	<0.01	<0.01	<0.01
	2013	0.3	0.02	22.18	0.46	1.86	0.03	0.52	0.04	0.42
	2014	0.3	0.07	0.35	0.13	0.67	0.03	0.52	0.04	0.42
	2015	0.14	0.06	0.51	0.12	0.75	0.03	0.52	0.04	0.42

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